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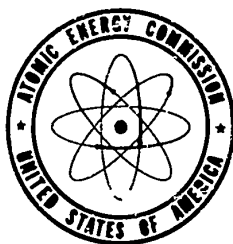
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UNITED STATES ATOMIC ENERGY COMMISSION

**ALL-UNION CONFERENCE ON THE APPLICATION OF RADIOACTIVE AND
STABLE ISOTOPES IN THE NATIONAL ECONOMY AND SCIENCE**

(ABSTRACTS OF PAPERS AND PLENARY SESSION PAPERS)

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ALL-UNION CONFERENCE ON THE APPLICATION OF RADIOACTIVE AND
STABLE ISOTOPES IN THE NATIONAL ECONOMY AND SCIENCE

(Abstracts of Papers and Plenary Session Papers)

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ACADEMY OF SCIENCES USSR
CENTRAL COMMITTEE ON UTILIZATION OF ATOMIC ENERGY
COUNCIL OF MINISTRIES, USSR

ALL-UNION CONFERENCE ON THE APPLICATION OF
RADIOACTIVE AND STABLE ISOTOPES IN THE
NATIONAL ECONOMY AND SCIENCE

ABSTRACTS OF PAPERS GIVEN IN THE SESSION ON ISOTOPE PRODUCTION
AND HIGH-INTENSITY γ -SYSTEMS

Moscow 1957

ISOTOPE PRODUCTION

CERTAIN PROBLEMS IN THE PRODUCTION OF RADIOACTIVE ISOTOPES IN A NUCLEAR REACTOR

E. E. Kulish

This paper is concerned with the first of the following two stages in the preparation of products which contain radioactive isotopes:

- a) the production of semi-finished isotopes by neutron irradiation, that is, certain standard samples of raw material which are irradiated in the reactor;
- b) the packaging of the semi-finished isotopes obtained by neutron irradiation and the synthesis of different chemical compounds containing these radioactive tracer isotopes.

To obtain semi-finished isotopes by neutron irradiation a set of chemical operations is carried out which is safe for reactor operation and which guarantees the highest purity of the materials which are irradiated in terms of smallest amounts and variety of radioactive impurities.

To obtain samples with the highest specific activity use is made of raw material which is rich in the appropriate stable isotope.

All raw material intended for irradiation is packaged in separate units and kept in standard aluminum containers. The dimensions of the containers and cases and the characteristics of the materials used in their fabrication are given.

All raw material is irradiated in an industrial nuclear reactor for three periods depending on the half-life, the effective cross sections, and the specific activity required in practice.

After irradiation the containers with the semi-finished isotopes are placed in transport containers with wall thickness which depends on the activity of the container and the hardness of the γ -radiation.

Before further processing of the irradiated raw materials, lumps containing γ -radiators are subject to measurements which are made to determine the specific and total activity of the semi-finished isotope.

The activity of other semi-finished isotopes is checked by measurements of the total neutron flux using a comparison with a standard cobalt sample.

For some of the semi-finished isotopes which are obtained in large amounts it is found expedient to irradiate the raw material in special large-volume containers, carrying out the primary chemical processing and the isotope separation immediately after irradiation. These methods are used to obtain C^{14} , Ca^{45} , Cl^{36} , and S^{35} .

A short description is given in the paper of special apparatus which has been constructed for this purpose. In this apparatus, under conditions which are safe for personnel, are carried out the separation of the original raw material and the extraction of C^{14} and Cl^{36} in the form of gases which are absorbed in absorption containers. The residual solutions are chemically purified from undesired impurities and Ca^{45} and S^{35} are obtained. The characteristics of the final products are presented.

Central Committee on the Use of Atomic Energy,
Council of Ministries, USSR

Editor
Yu. S. Prolov

PRODUCTION OF SEVERAL RADIOACTIVE ISOTOPES AT A 10-MEV
DEUTERON CYCLOTRON AND A THEORETICAL ESTIMATE FOR
THE REACTION CROSS SECTIONS AS A FUNCTION
OF DEUTERON ENERGY

I. P. Selinov, P. P. Dmitriev, I. I. Zhivorovsky, N. N. Krasnov,
B. N. Khaprov, Z. Z. Latypov, and M. Z. Maksimov

Production of radioactive isotopes at a 1-meter 10-Mev deuteron cyclotron.

1. Production of radioactive isotopes by deuterons.

The isotopes Mn^{54} and Mn^{56} have been obtained by irradiating chromium and the isotope Zn^{66} has been obtained by irradiating copper in the internal deuteron beam. A target, the head of which is a copper cylinder 28 mm in diameter was used. The internal surface of the head was water-cooled while the external surface was plated with chromium or copper from which the zinc had been removed by a special purification process.

It was possible to carry on extended irradiation of the target without noticeable effects on the surface using a mean ion current of 250 μ amp. To extract the manganese isotopes without the use of a carrier manganese-ion adsorption in iron hydroxide with subsequent extraction of the iron by diethyl ether was used. The Zn^{66} was separated by extraction of the zinc with a solution of dithizone in chloroform with subsequent rinsing in hydrochloric acid.

The isotopes Na^{22} and La^{138} were obtained by deflecting the ion beam. To obtain the sodium isotope a slab of magnesium 0.5 mm thick was set up as a target for the deflected beam. The inner side of the irradiated slab was water-cooled. The dimensions of the irradiated surface were $2.5 \times 15 = 37.5$ cm². The target was bombarded by a current of 100 μ amp. The Na^{22} was separated without a carrier by triple precipitation of the magnesium in carbon-free NH_4OH .

The isotope La^{138} was obtained by irradiating barium oxide using the (d, n) and (d, 2n) reactions. The target was bombarded by a beam current of 80 μ amp. To separate the La^{138} from the barium oxide a method was used in which lanthanum is absorbed in iron hydroxide with the subsequent extraction of $FeCl_3$ by diethyl ether. The isotopes Zn^{66} and La^{138} were produced for investigation by γ -spectroscopy, which is carried out in the Institute, and the isotopes Na^{22} , Mn^{54} , and Mn^{56} were prepared at the request of other institutions.

2. Production of radioactive isotopes by fast neutrons.

Fast neutrons, with energies above 16 Mev, can be obtained by using a target of boron or lithium. A measurement of the neutron yield using as a detector the radioactive isotope C^{14} which is formed in the $C^{12}(n, 2n)$ reaction indicates that the neutron yield from a lithium target is 3.5-4 times greater than that of a boron target. Thus, a target of metallic lithium was used to obtain the radioactive isotopes.

The fast neutrons were used in work carried out under a program for finding new isotopes which are produced in (n, p) and (n, α) reactions. The activity of the radioactive isotopes so produced has been found sufficient both for the discovery of new isotopes (Ga^{76} and others) as well as for the identification of isotopes with unverified mass numbers (Ga^{74} , Ga^{75}).

3. Calculation of the product yield of the reactions as a function of deuteron energy.

In the use of these or other nuclear reactions for obtaining isotopes, in a number of cases it is necessary to have at least a rough idea of the dependence of yield on the energy of the incident particles. There is very little experimental data concerning the isotope yield dependence as a function of energy. Hence, it is of interest to carry out the calculation of these functions by theoretical analysis.

On the basis of the statistical theory, M. Z. Maksimov has carried out an estimate of the yield of certain isotopes in the irradiation of thick targets by deuterons with energies up to 20 Mev.

The results of the calculations are shown in the form of curves for the following reactions: $Mg^{24,25}(d, \alpha)$; $d, \alpha n Na^{22}$; $C^{12,14}(d, n; d, 2n) Mn^{54}$; $Fe^{54,57}(d, \alpha; d, \alpha n) Mn^{56}$; $Cu^{65}(d, 2n) Zn^{66}$; $Ba^{136,137,138}(d, n; d, 2n; d, 3n) La^{138}$.

Central Committee on the Use of Atomic Energy,
Council of Ministers, USSR

CHEMICAL-SPECTRAL ANALYSIS OF HIGH-PURITY MATERIALS USED IN
REACTOR CONSTRUCTION AND IN THE MANUFACTURE OF RADIOISOTOPES*

A. G. Karabash and Sh. I. Peizulaev

This work presents the general characteristics of the chemical-spectral analysis method of the following high-purity metals (and their compounds): Na, K, Be, Mg, Ca, Sr, Ba, Al, Ga, Si, Ge, Sn, Pb, Bi, Au, Fe, Ni, Ti, Zr, Cr, Mo, V.

In each of these metals the chemical-spectral method provides for a common quantitative determination, in one spectrogram, of a large number (15-25) of impurity elements, usually the following: Be, Mg, Ca, Ba, Al, Ti, V, Cr, Mo, Mn, Fe, Ca, Ni, Cu, Ag, Au, Zn, Cd, In, Ge, Sn, Pb, Sb, Bi, Ga, Ti, Te, Pt.

The impurities B, Si, As, Li, Na, K are determined separately.

The methods which have been developed are based on the general idea of the separation of base elements by means of selective reactions with the simultaneous concentration of a large number of impurity elements and the subsequent spectrographic determination of all impurities in the concentrate.

The concentration of the impurities is accomplished by conversion of the base element into another phase - solid (by cooling), liquid (by extraction, flotation), or gaseous (by evaporation) - with subsequent separation from the impurity concentrate. These selective reactions and the conditions for which quantitative concentration of the impurities can be carried out without loss are chosen in the hope of finding a single suitable operation. The impurity concentrate is prepared in powder form by fixation of the individual impurities with a small amount of the appropriate base. In this operation the factor by which the impurity is enriched in the concentrate ranges from 20-100.

Standards are also prepared in the form of powder by introducing into the spectrally pure base all the elements being determined; the same standards are used for the concentrates and unenriched samples.

The conditions for spectral analysis of different metals are almost identical. In all cases a spectroscopy of medium dispersion is used (ISP-22, ISP-28, Q = 24). The spectra are excited by a dc arc between carbon electrodes at a current of 12 amp. The spectra of the unenriched samples and the concentrate are photographed together. In analysis of metals with simple spectra the exposure is made for total combustion. In analysis of metals with complicated spectra, fractional distillation of the carrier is used or the impurity concentrate may be fixed after complete separation of the base element from the other ("universal") base (BeO , SiO_2). Calibration curves are drawn using the coordinates ($\log I$, $\log C$).

Because of the chemical concentration effect a considerable improvement of the relative sensitivity of the spectral determinations obtains (from 20 to 100 times); this applies to all impurities. The sensitivity in a determination of the majority of the above-mentioned elements is $10^{-4} - 10^{-5}$.

* The following took part in the development of these methods under the direction of A. G. Karabash and Sh. I. Peizulaev: R. L. Slyusareva, Z. N. Samonova, L. S. Krauz, N. P. Sotnikova, N. I. Smirnova-Averina, G. G. Morozova, L. S. Romanovich, I. I. Smirenkina, V. M. Lipatova, S. K. Sazanova, V. P. Usacheva, L. I. Pugacheva, F. A. Kostareva, P. D. Gorchabev, E. F. Voronova, N. T. Kostereva, F. L. Babina, A. I. Elvatskaya, N. N. Kuznetsova, and V. S. Moieva.

The chemical-spectral methods are characterized by relative error of approximately 20% in the determinations of traces of the elements. The methods were tested using artificial mixtures of unknowns and also by carrying parallel determinations using chemical and spectral analysis. To get a quantitative picture of the effect of concentration on the impurities, the distribution of traces of the elements between phases under the conditions of the analysis was investigated. Radioactive indicators and activation-analysis methods were also used for this purpose.

These chemical-spectral methods, in conjunction with spectral, chemical, and activation-analysis methods, can be used in control of high-purity materials used in reactor construction and also for analytical control of raw materials and semi-finished products in the manufacture of artificial radioisotopes.

Central Committee on the Use of Atomic Energy,
Council of Ministries, USSR

QUANTITATIVE SPECTRAL ANALYSIS OF IMPURITIES IN RADIOACTIVE PREPARATIONS

V. V. Lvov and G. I. Kibisov

The use of spectral analysis in control of the purity of radioactive materials has the following advantages: only small amounts of the material are required to perform an analysis (2-50 g);

the time required for analyzing several samples can be held down to 3-4 hours and the manipulation of active materials does not take more than 1-1.5 hours.

This paper points out the great simplicity of the methods, the fact that tests for all the desired materials in a sample can be carried out simultaneously and the fact that the same method can be used for preparations of different composition. There is some reduction in accuracy as compared with the analysis of nonradioactive materials. In general, however, the errors are of the order of 5-8% which is satisfactory for the present purposes.

The spectrum is excited by an α or γ source examined with standard equipment (ISP-22 spectrograph). Before analysis solid materials are converted into solutions and if this is not possible, are used as powders.

To protect personnel from the radioactive aerosols produced in the excitation of the spectra, a simple chamber was constructed and maintained at less-than-atmospheric pressure. The other operations are carried out in a lead-lined box.

As an example, we present the determination of P and Fe in CdS powder and the determination of Co, Mn, and Sb in FeCl_3 solutions. The cadmium sulfide is analyzed in the form of a powder which is deposited on the carbon electrodes as a dispersion in glycerin. The FeCl_3 solution is deposited on a plane electrode prepared beforehand from a solution of polystyrene. The presence of the above-mentioned elements can be detected if they are present in concentrations of a thousandth of a percent. This does not seem to be the limiting sensitivity.

State Institute for Applied Chemistry

CONSTRUCTION OF α -, β -, AND γ -SOURCES USING OXIDE FILMS ON ALUMINUM AND ALUMINUM ALLOYS

M. S. Petrova

1. In a number of fields of medicine, science, and technology there is frequent need for hard sources of α -, β -, and γ -radiation with different configurations, size, and activity.

Up to the present time the construction of such sources with phosphorus, carbon, strontium, sulfur, thallium, and also certain γ -radiators, for example, cobalt, zinc, iron, etc., has not been feasible in practice.

2. The purpose of the present work is to explore the possibility of constructing sources of β - and γ -radiation using artificial radioisotopes, through the use of a universal method which exploits the properties of oxide films on aluminum and its alloys "charged" by different chemical reagents.

3. The properties of oxide films artificially produced on aluminum and aluminum alloys are affected to a great extent by the techniques employed in their formation. The films may be elastic or brittle, thick or thin, very porous or slightly porous.

The films can be produced by thermal, chemical, or electrochemical means. The best results are obtained by anodizing. By changing the composition of the solutions, the temperature, the duration of treatment, the voltage, and current density (in electrochemical oxidation), and by choosing the different "charging" techniques and reagents properly (dyes, oils, inhibiting agents, lacquers and other chemical reagents), films with different characteristics can be produced.

By controlling the technique of film formation it is possible to produce on a practical scale films for decorative purposes, anticorrosion use, electrical insulation, etc.

The properties of oxide films obtained by electrochemical methods which are then charged chemically have been used to make β - and γ -sources with artificial radioisotopes.

4. Oxide films with a high filling factor were obtained using a sulfuric-acid anodizing scheme and hydrochloric-acid processing.

In the first case an ordinary sulfuric acid bath is used (20% solution of sulfuric acid, dc voltage approximately 18 volts, initial anode current density 1.5 amp/dm², electrode temperature approximately 18°, lead-plate cathode).

In the second case the oxidation is carried out in a hydrochloric acid electrolyte (2% solution) using ac voltages up to 120 volts.

5. The method has been checked using three oxidation techniques and eight isotope solutions Co^{60} , Zn^{65} , Ti^{44} , P^{32} , C^{14} , S^{35} , with various degrees of charging.

6. These experiments reveal that after rinsing and fixation of the films, one has hard β - and γ -sources which are characterized by high mechanical surface stability and which do not contaminate objects with which they come in direct contact.

The activity of the sources can be varied over wide limits by changing the conditions of formation and charging of the films; for example, by changing the exposure in the electrolyte and in charging it is possible to change the activity of the phosphorus samples by more than a factor of a thousand.

7. Through the use of the method which is described here it is possible to fabricate hard α -, β -, and γ -sources in the shape of slabs, tubes, cylinders, spheres, and any other desired configuration which can be fabricated from aluminum and aluminum alloys. By covering desired sections of the sources these can be kept from becoming radioactive.

Sources of this type can be used in medicine, (applicator), apparatus design, dosimetry, printing, and textile manufacture (for removal of static charges) and in many other fields of the national economy.

Academy for Medical Sciences, USSR

ENRICHMENT OF STABLE ISOTOPES BY THE ELECTROMAGNETIC METHOD

V. S. Zolotarev

This report presents data from which it is possible to make estimates of the rates at which isotopes of various elements can be separated by the electromagnetic method. For the sum of all the isotopes of a given element this quantity ranges from hundreds of milligrams to several grams per day (for continuous operation) with one ion source. The rates for individual isotopes depend on the relative abundances in the natural element.

Information is given on the weight of enriched isotopes obtained for research purposes: these fluctuate from several tens of milligrams to several grams depending on the relative abundances.

The report also contains a table of the enriched isotopes which have been separated on a technological scale in the U.S.A., U.S.S.R., and England.

In conclusion the elements already separated in the Soviet Union and those on which work will be carried out in 1957 are listed.

Institute for Atomic Energy
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WORKING MATERIALS FOR ISOTOPE SEPARATION BY THE ELECTROMAGNETIC METHOD

B. A. Alekseev

In the foreign literature which is concerned with the working materials used in electromagnetic separation of isotopes there is no information as to the criteria used in the choice of working materials or the pertinent requirements. The latter can be formulated starting from an analysis of the working material in the basic stages of its conversion during the separation process: evaporation; ionization and dissociation; removal of nonionized material in the vacuum chamber of the separation apparatus.

The use of materials in the form of elements or simple compounds is indicated. It is desirable that the working material be one of high purity, i.e., a high number of impurities is unfavorable for the evaporation process since these tend to disturb the uniformity of the process and to complicate the separation. However, frequently compromise solutions must be found, particularly when there is no ion source of the appropriate type or when it is difficult to acquire a given material.

In three available ion sources which cover working-material evaporation ranges of 20-900°, 900-2000°, and 2000-3000° it is possible to use all the elements except tungsten and possibly tantalum. In this case the natural limitation is the problem of obtaining the desired material in the form of the element.

Sometimes it is desirable to depart from the use of chemically pure working materials, particularly when these are difficult to obtain. For example, in separating isotopes of the rare-earth elements it is convenient to use concentrates, that is, in the electromagnetic separation process there is a rather sharp mass resolution and the chemist is provided with a relatively simple answer to the problem of separating binary mixtures of isobars or purification of isotopes from traces of contamination by neighboring elements. This simplifies considerably the separation of isotopes of the low-abundance elements. The method was checked in the separation of gadolinium isotopes; a 63% concentrate was used.

Institute for Atomic Energy
Academy of Sciences, USSR

HIGH-TEMPERATURE ION SOURCE FOR ELECTROMAGNETIC SEPARATION OF ISOTOPES OF ELEMENTS OF THE PLATINUM GROUP

V. M. Gus'ev

1. The basic need for the development of a high-temperature ion source with operating temperatures ranging to 2700° for separation of isotopes of elements of the platinum group (Pd, Pt, Rh, and Ir) is connected with the thermal instability of all known compounds of these elements and the fact that it is impossible to use existing low-temperature sources.

2. A design for the construction of a high-temperature ion source is described in which the crucible and discharge chamber are heated by electron bombardment. Data are given for the electron gun which provides a hollow cylindrical beam (100-200 ma) with energies ranging from 20-25 keV which is used to heat the discharge chamber to a high temperature. The thermal shielding of the source is also described.

3. Operation of the source for separation of palladium isotopes. Data are given on the dependence of the ion current emitted from the source and the current focused on the collector as functions of the pressure in the ionization space, the discharge voltage, and the accelerating voltage. Also the level of oscillations of the ion-beam current is described.

4. A description is given of a collector which is used for the simultaneous collection of six palladium isotopes.

5. Results are given on the separation of Pd isotopes in a small electromagnetic separator. Approximately 300 mg of enriched isotopes of palladium are obtained with an hourly consumption of metallic Pd of 0.5-0.6 g.

In the samples which were obtained the concentration of the respective isotopes was increased as follows:

Pd^{102} from 0.8 to 21.3%;
 Pd^{104} from 9.3 to 44.3%;
 Pd^{106} from 22.6 to 53.7%;
 Pd^{108} from 27.2 to 70.3%;
 Pd^{110} from 26.8 to 74.4%;
 Pd^{112} from 13.5 to 44.2%.

6. The high-temperature source is useful for separation of small amounts of isotopes of other solid elements in those cases in which it is convenient to work with the pure elements and not compounds.

Central Committee on the Use of Atomic Energy,
Council of Ministries, USSR

MASS-SPECTROMETER WITH AN INHOMOGENEOUS FIELD FOR ISOTOPE ANALYSIS OF LIGHT ELEMENTS

N. E. Alekseevsky, A. V. Dubrovina, G. I. Kosorov, G. P. Prudkovsky,
S. I. Shchelynnin, T. K. Shuvalova, S. I. Filimonov, and V. I. Chekin

By using an inhomogeneous magnetic field it is possible to increase the resolving power of a mass-spectrometer without increasing the size of the magnet.

An axially symmetric magnetic field which decreases in the radial direction is used. With this configuration the dispersion and resolving power are increased by a factor of $\frac{1}{1-n}$, where

$$n = \frac{dH}{H} \frac{r}{dr} \text{ for } r = r_0,$$

and r_0 is the radius of the equilibrium orbit.

The ion beam of the paraxial trajectory at the equilibrium radius is focused in the radial and axial directions after deflection in the magnetic field through angles

$$\phi_r = \frac{\pi}{\sqrt{1-n}}; \quad \phi_z = \frac{\pi}{\sqrt{n}}.$$

In the case of sectored magnetic field with an ion-beam deflection angle $2\phi = 180^\circ$, focusing is realized if the source and collector are placed at identical distances f from the boundary of the magnetic field,

$$f = r_0 \frac{\text{ctg } \sqrt{1-n}}{\sqrt{1-n}}.$$

A number of instruments based on this principle have been constructed. The inhomogeneous field is provided by an electromagnet with conical pole pieces.

In a glass instrument with radius $r_0 = 40$ mm for $n = 0.89$, and $f = 208$ mm, with slit widths in the source and collector of 0.2 and 0.4 mm, respectively, the resolving power for half-width at half maximum is 400; with this resolving power it is possible, for example, to resolve completely the mass doublet ($4\text{He}^+ - \text{D}_2^+$).

A large all-metal instrument with the following parameters $r_0 = 350$ mm, $n = 0.87$, and $f = 1400$ mm has a dispersion of 27 mm for 1% change in mass. Using 0.2 mm slits in the source and collector a resolving power of approximately 7500 is achieved (half-widths). In the mass spectrograms which are obtained it is easy to resolve the lines of the doublet at $m = 20$ ($\text{Ar}^{36+} - \text{Ne}^+$) and the multiplet at $m = 28$ ($\text{CO}^{14+} - \text{C}_2\text{H}_4^+$). The instrument is characterized by a high "illumination," an ion current at the collector of 10^{-3} amp for an operating pressure in the ion source of $1 \cdot 10^{-8}$ mm Hg. In a prototype instrument with a radius $r_0 = 152$ mm, a resolving power of approximately 11,000 was achieved using slits of 0.05 mm in the source and in the collector. The instruments described here have been widely used in isotope analyses of helium and hydrogen. In analyzing helium which contains He^3 it is important to resolve the multiplet at mass 3 since the hydrogen peak due to the residual gases in the instrument may distort the results of the measurement.

The application of instruments with high resolving power for analysis of hydrogen-deuterium mixtures makes it possible to obtain the D content in one measurement and does not require analyses at different pressures as is the case if the multiplet at mass 3 cannot be resolved.

In analyzing mixtures with high deuterium content the use of high-resolution instruments makes it possible to resolve the lines for H_2^+ and D_2^+ .

In addition to the use of an inhomogeneous field as a means of increasing resolving power, in a number of cases it is convenient to use such a field to maintain the sensitivity of a mass-spectrometer when the slit widths in the source and collector are increased. A glass instrument of this type with $r_0 = 50$ mm and slits 0.8 and 2 mm has a resolving power of approximately 60. The maximum ion current for $p = 10^{-8}$ mm Hg in the source reaches 10^{-8} which makes it possible to measure concentrations of the order of 10^{-4} .

Institute for Physical Problems
Academy of Sciences, USSR

CERTAIN PROBLEMS IN THE THEORY OF ISOTOPE SEPARATION

A. M. Rozen

The y - x diagram for a cascade of distillation or exchange columns with chemical phase conversion is considered. Two methods of determining material flow are compared: the usual method (by minimum fractional distillation number) and a special method (by the limiting capacity of the column).

Formulas are presented which relate the enrichment and the number of transfer units (or theoretical barriers) of the columns which operate at any concentration of the distilled component. The dependence of enrichment on output is linear only at low concentrations. The operation of the first column of a cascade is considered and the optimum input conditions are treated.

For a variable optimum input the dependence of enrichment on output is not linear; for a fixed height of the input it becomes linear but the enrichment which can be achieved is reduced. In the case of the cascade of a concentration column which operates in the region of low concentrations of the distilled component the total enrichment depends linearly on output. If the first column is a fractionating column and the next operates in the region of high concentrations the dependence of enrichment on output becomes nonlinear. Several types of cascade are considered. It is shown that the limiting capacity of a cascade is equal to the capacity of the first column divided by the cascade constant. The latter is found from the constants for the individual columns by the same rule as for electrical resistances.

A theory is developed for concentration via a two-temperature exchange process with replacement of chemical phase conversion by distillation at another temperature. This method is similar to separation by absorption-desorption. The equation for the operating line cannot be obtained from material balance; a complete solution of the equations of enrichment and balance is required. A feature of the process is the relatively pronounced enrichment which obtains for a definite relation between the flow of liquid and gas (equal to the arithmetic mean of the distribution factors for both temperatures). This feature is connected with the location of the operating lines in the "yoke" between the two equilibrium curves (the bend in the operating line reduces the concentration pressure head) and limits the application of this method to systems with high values of the separation factor. A theory for a cascade of two-temperature columns is developed.

Consideration is given to nonstationary processes in the individual columns of the cascade. Under certain conditions the concentration distributions over the height of the column are similar for the transient and equilibrium cases as are the kinetic curves at different points; this situation is due to the exponential kinetic law. For a single column fed by a liquid with a fixed concentration of the distilled component the exponent (relaxation time T_0) has a simple physical significance: it is the time which would be required for accumulation in the column of an equilibrium supply of the distilled component, if the accumulation rate were constant and equal to the initial value. In the actual accumulation rate the exponent decreases with time. Hence the accumulation time T is larger than the relaxation time and depends logarithmically on the extent to which equilibrium is approached (for 99% $T = 5T_0$). It is shown that in the case of a column which operates in a cycle with two reservoirs (feed and output) under certain conditions there is a "zero point" in which the concentration does not change with time. In this case the lower part of the column acts like a column with a fixed feed. The kinetics of a number of more complicated cases are also considered - columns with fractionating stages, etc.

A method is developed for deriving the kinetic equations from similitude considerations.

Central Committee on the Use of Atomic Energy,
Council of Ministries, USSR

ISOTOPE SEPARATION BY GASEOUS DIFFUSION

I. G. Gverdtsiteli and V. K. Tshhakaya

The idea of using diffusion in gas flow for accomplishing separation was proposed by Hertz, who separated a neon-helium mixture by this process in 1922.

The further development of the method made possible the successful separation of a number of isotopes.

Although it is characterized by a high separation factor this type of device has a small capacity and with it only small indicator amounts of enriched isotopes can be obtained.

This report contains a description of a separation element (diaphragm pump) the development and study of which was carried out under the direction of Hertz in 1946-1952. The version described here combines a high separation factor with a high specific capacity.

Experimental results given in the report were obtained in 1956 with a cascade of 70 separation pumps. The pumps are all glass with the exception of the diaphragms. The diaphragms are steel tubes 15 mm in diameter with wall thickness of 0.3 mm and contain 500 apertures 0.4 mm in diameter. The operating vapor is mercury. In one pump, used to separate isotopic mixtures, the following separation factors were obtained:

$$\frac{P_{Ne^{22}}}{P_{Ne^{20}}} = 1.2; \frac{P_{A^{22}}}{P_{A^{20}}} = 1.15; \frac{P_{C^{13}H_4}}{P_{C^{12}H_4}} = 1.09; \frac{P_{Kr^{84}}}{P_{Kr^{82}}} = 1.03.$$

The operating pressure is 10 mm Hg. A general procedure has been developed to estimate the separation factor as a function of relative difference in diffusion factors of the isotopes in the region $0.005 \leq \frac{\Delta D}{D} \leq 0.05$.

In a cascade of 70 pumps the following concentrations were obtained: $C^{13}H_4 = 77\%$, $Kr^{84} = 92\%$, and $A^{22} = 45\%$.

The specific capacity of the separation pumps exceeds considerably that of the old type.

Central Committee on the Use of Atomic Energy,
Council of Ministries, USSR

DIFFUSION COLUMN FOR ISOTOPE SEPARATION

G. F. Barvikh and R. Ya. Kuchеров

A diffusion separation column which has been successfully used to separate isotopes of the light elements is described.

The column uses as the primary mechanism diffusion in a vapor jet (the so-called second Hertz method). To achieve significant enrichment in one separation stage, it is necessary, following Clusius and Dickel, to have an extended convection flow in the upward direction on one side of the diaphragm and in the downward direction on the other. These flows are produced as a consequence of the application of an auxiliary gas in the lower part of the column.

The column is fabricated from stainless steel. The length of the diaphragm is 1 m, the diameter 40 mm.

Oxygen, nitrobenzene, and other gases have been used as the auxiliary gas.

The operating pressure ranges from 30-200 mm Hg.

Experimental studies of the column have been carried out using isotope mixtures of neon, argon, and carbon. The following isotope separation factors were obtained:

$$\frac{P_{Ne^{22}}}{P_{Ne^{20}}} \sim 9, \quad \frac{P_{A^{22}}}{P_{A^{20}}} \sim 5, \quad \frac{P_{C^{13}H_4}}{P_{C^{12}H_4}} \sim 2.6.$$

A theoretical analysis of the diffusion column is given. It is shown that it can be reduced to the analysis for a square cascade. In a cascade of 10 columns Ne^{22} was concentrated. For a yield of 400 mm/day the concentration of the Ne^{22} was approximately 99%.

Central Committee on the Use of Atomic Energy,
Council of Ministries, USSR

RECTIFICATION COLUMN FOR OBTAINING BF_3 ENRICHED IN B^{10}

Yu. Myulenfordt, G. Elvert, and T. A. Gagua

The relative difference in the equilibrium pressures for saturated vapors of $B^{10}F_3$ and $B^{11}F_3$ at a temperature of $-103^\circ C$ and a pressure 630 mm Hg is 0.0082. This makes it possible to realize a high efficiency rectification process.

The rectification apparatus is approximately 16 m in height. The height of the rectification column is 12 m and the internal diameter 12 mm. The tube is fed by a nozzle formed by a ring of constantan wire with an inside diameter of 1.2 mm. The diameter of the wire is 0.25 mm. The surface of the nozzle is approximately $50 \text{ cm}^2/\text{ml}$. The fraction of unoccupied volume is 0.7.

Since $B^{10}F_3$ is less volatile than $B^{11}F_3$ the extraction of the enriched product takes place at the base of the column. The rejection tank is at the upper part of the column.

The column is cooled by a special system. The refrigerant is ethylene which in turn is cooled with liquid oxygen through a controlled heat exchanger system.

The following optimum parameters have been established on the basis of two years of operation: number of theoretical barriers ~ 600 ; maximum concentration of $B^{10}F_3$ in a closed system is 98%; for a yield of 4 ml/day the concentration of $B^{10}F_3$ is approximately 80%; extraction factor 1.2; consumption of liquid oxygen is 8 liters per liter of enriched material.

Central Committee on the Use of Atomic Energy,
Council of Ministries, USSR

INVESTIGATION OF THE SEPARATION OF ISOTOPES OF THE LIGHT ELEMENTS

N. M. Zhavoronkov, O. V. Uvarov, and S. I. Babkov

Work on the separation of stable isotopes and an investigation of their properties was initiated in the USSR by A. L. Brodsky and his colleagues in 1936-1937 but the work was not emphasized until a later period. The report contains the basic results obtained at the Institute on studies of the separation of oxygen, nitrogen, boron, carbon, and silicon.

The isotope separation factors for the following systems have been measured over a wide temperature range: $H_2O^{16}-H_2O^{18}$, $B^{10}Cl_3-B^{11}Cl_3$, $C^{12}H_4-C^{13}H_4$, $C^{12}H_4-C^{13}C^{12}H_4$, and $C^{12}H_4-C^{13}C^{13}H_4$. Conclusions have been reached as to the feasibility of using these systems for obtaining low-abundance isotopes. Furthermore, certain results have been obtained concerning the dependence of the isotope separation factor in carbon on the structure of the molecule.

In processes which require a large number of separation stages the accumulation rate of one of the components is of great interest. Using separation of nitrogen and oxygen the kinetics of these processes have been studied and equations have been derived which apply over a wide enrichment range, are in good agreement with experiment and are useful in practical applications.

The methods which have been developed for separating isotopes of oxygen, nitrogen, and boron make it possible to obtain concentrations of these isotopes. Using a laboratory apparatus water with a content of H_2O^{18} up to 24.5 mol % has been obtained (in ordinary river water H_2O^{18} is approximately 0.2 mole %). By enlarging the system it was possible to obtain approximately 10 kg of NH_4NO_3 per year enriched in the ammonium nitrogen to 30-20 mole % (the content of N^{15} in natural nitrogen is 0.38 mole %). It has been found feasible to use rectification of boron chloride to obtain B^{10} . In one column 12 m high it is possible to obtain a product containing 80% $B^{10}Cl_3$.

However it has been shown experimentally that rectification of $SiCl_4$ cannot be used to separate silicon isotopes. It is also not feasible to obtain C^{13} by rectification of ethane and ethylene because of the small separation factor.

At the present time it may be assumed that the basic solution has been found for the problem of separating isotopes of the light elements which are most important for practical and scientific purposes. However much still remains to be done in the development of more effective methods of obtaining highly enriched concentrates of the low-abundance isotopes and in studying their physical and chemical properties.

L. Ya. Karpov Physicochemical Scientific Research Institute
Ministry of Chemical Industries, USSR

SEPARATION OF CARBON ISOTOPES

N. N. Tunitsky, G. G. Devyatykh, M. V. Tikhomirov,
A. D. Zorin, and N. I. Nikolaev

The bicarbonate method of separating carbon isotopes has been studied with different nozzles, pressures, and temperatures. The results of the experiments can be explained starting from the assumption that in all cases the nozzles have no catalytic effect. The time to reach the equilibrium state in a system of this kind is extremely long.

The isotope separation factors have been measured for equilibrium of liquid and gaseous methane and carbon dioxide. The following values of the isotope separation factors were measured:

$$\frac{PC^{13}H_4}{PC^{12}H_4} = 1.0098; \quad \frac{PC^{18}O}{PC^{16}O} = 1.0103; \quad \frac{PCO^{16}}{PCO^{18}} = 1.0043$$

(for normal boiling temperatures).

An attempt was also made to investigate theoretically the value of the separation factor. The results of the calculations are in satisfactory agreement with the experimental data obtained by other authors and ourselves.

Experiments have been carried out on the separation of carbon isotopes in low-temperature nozzle columns of lengths 3.75 and 10 m. In the 3.75 m column, in a period of two days an enrichment of the C^{13} isotope by a factor of 3.65 was achieved and the O^{18} isotope by a factor of 2.46 which corresponds to a height for a theoretical barrier of 2.7 cm. In using the nozzle the specific flow was 3.5 ml/cm² · min.

To obtain small amounts of CO with high enrichment in C^{13} and O^{18} a thermal diffusion method was used. In this scheme in a 1 m-thermal diffusion column an enrichment of C^{13} by a factor of 1.7 was achieved. It is

interesting to note that the theoretical value of the ratio or the logarithms of the enrichment factors in carbon and oxygen is 2 while in the present experiments this quantity fluctuates between the values 1.2-1.3.

A comparison of the different methods of separating carbon isotopes indicates that the most efficient scheme is the low-temperature rectification of carbon monoxide or methane.

L. Ya. Karpov Physicochemical Scientific Research Institute
Ministry of Chemical Industries, USSR

LOW-TEMPERATURE METHODS FOR SEPARATING HELIUM ISOTOPES

V. P. Peshkov and V. M. Kuznetsov

Because of the development in recent years of work with the very rare isotope of helium, He^3 , a need has arisen for developing effective methods for separating mixtures of He^3 - He^4 . Of most interest are the low-temperature methods which provide rather fast and reliable extraction of He^3 from the mixture.

A consideration of the liquid-vapor diagram of solutions of He^3 - He^4 shows that this system is not ideal. Furthermore, at temperatures below 0.8° K a separation of the liquid into two phases takes place.

Along with rectification, to obtain enrichment of weak solutions of He^3 and He^4 it is feasible to use thermal osmosis (extraction of He^4 by superfluid flow through a filter). A theoretical expression has been obtained for the limiting enrichment in thermal osmosis and it is found to be in satisfactory agreement with the experimental data.

A system has been constructed with which natural helium can be enriched in the isotope He^3 and in which it is possible to prepare up to 3 nm³/hour. The enrichment factor reaches $2 \cdot 10^4$.

By integrating the differential equations for mass exchange one obtains a basic relation for calculating the characteristic of the tubular rectification column and certain numerical formulas for nozzle columns. The theoretical results allow one to estimate the efficiency of the column for different modes of operation.

By combining thermal osmosis with rectification of a 3.6% mixture 4nl of He^3 with a purity of 99.995% has been obtained. In this case the product extraction rate was 10 nl/hour. The untreated yield was less than 0.25-0.3 nl He^3 . The time required for equilibrium in the rectification column is of the order of 10 seconds.

Institute for Physical Problems
Academy of Sciences, USSR

RELATIVE ABUNDANCES OF THE ISOTOPES OF GERMANIUM AND PALLADIUM

K. G. Ordzhonikidze and G. N. Zubareva

The accuracy of the measurements of Simpson and Bleakney of the relative content of the isotopes of palladium is of an order of magnitude lower than that which can be achieved with present day mass-spectrometers. Nevertheless, at the present time the data of these authors remain in the isotope tables. In a short report published in 1953 new values for the relative abundances of the isotopes of palladium were given and these were not

In agreement with the values given in the tables. The method and accuracy of the measurements were not discussed in the report.

To evaporate metallic palladium an evaporator was built with a heating capacity of 15-20 w; this source furnishes intense stable palladium-ion beams. The stability of the ion current was improved by the addition to the palladium of tungsten powders; these powders have a favorable effect on the evaporation process.

It was found that the interaction of vapors of palladium and mercury improves the palladium-ion yield; this is characteristic of palladium and requires further study.

The relative abundances of palladium isotopes were determined from singly, doubly, and triply charged palladium ions. The accuracy of the measurements of the isotope contents of palladium with the singly charged ions is 0.1-0.4%. In the doubly and triply charged ions it is somewhat less. The palladium isotope abundances which were obtained are in poor agreement with the values given in the tables but are in good agreement with the 1953 results.

Using the method which has been developed it is possible to make isotope analyses of small amounts of palladium (30-40 μ g).

The isotopic composition of germanium has already been determined by different authors and ourselves from gaseous halide compounds, the production of which may be accompanied by separation of the isotopes. Hence, in order to avoid difficulties connected with control of the isotopic composition or obtaining 100% reaction yields in the production of gaseous halide compounds of germanium, it is desirable to measure the isotopic composition of metallic germanium without any chemical treatment.

The use of a quartz evaporator in the ion source of a mass-spectrometer creates a number of difficulties; these were avoided by the use of an evaporator of tungsten or tantalum. The addition of tungsten powder to the germanium appeared to be more effective than in the palladium case.

The accuracy of the measurements of the relative content of the germanium isotopes in metallic germanium (0.8-1.1%) is one half-order of magnitude poorer than in the gaseous germanium tetrafluoride (0.1-0.5%). Hence, in making precision measurements it is mandatory to use GeF_4 in isotope analysis of small quantities and measurements of ordinary samples the use of metallic germanium is recommended.

An isotope analysis was made of samples of germanium enriched by an electromagnetic separation process. The measurements have been carried out both for gaseous germanium tetrafluoride and metallic germanium.

Central Committee on the Use of Atomic Energy,
Council of Ministries, USSR

HIGH-INTENSITY γ -SYSTEMS

PROBLEMS AND TRENDS IN THE DESIGN OF HIGH-INTENSITY γ -SYSTEMS

V. I. Sinitzyn

1. The field of application of high-intensity γ -systems.
2. Basic requirements for high-intensity γ -irradiators: dose and dosage rate, geometry for uniform dosage field, capacity, mode of operation, control, monitoring, and shielding.
3. Possible forms of sources for γ -radiation which can be used in high-intensity γ -systems: isotopes prepared in nuclear reactors, uranium fission products, combination of radiators.
4. Short survey of the status of the theory of high-intensity γ -irradiators and directions for new work.
5. Basic problems in the construction and technical design of high-intensity γ -systems: shielding methods, techniques for charging and removing sources, dosimetry control, etc. Basic system design trends.
6. Trends in the solution of technico-economic problems, training of personnel and literature publication.

Central Committee on the Use of Atomic Energy
Council of Ministries, USSR

PRINCIPLES AND TECHNIQUES IN THE UTILIZATION OF RADIOACTIVE MATERIALS AS HIGH-INTENSITY γ -SOURCES IN RADIOBIOLOGY AND MEDICINE

A. B. Bibertal, V. G. Khurshchev, and U. Ya. Margulis

1. Experiment on the application of radioactive materials as sources of γ -radiation in biology and medicine.
2. Requirements which arise in characteristic irradiators and problems in the construction and technical design of apparatus as related to radiation problems.
3. High-intensity γ -systems used in biology and medicine may be divided into four basic groups in accordance with the purposes for which they are intended. The basic principles, characteristics, and construction features of these types.
4. The characteristic properties of different systems and the basic expressions for calculating dosage fields of various radiators; experimental results.
5. Fundamental steps required for obtaining a wider acceptance of isotope sources in medicine and biology.

Academy of Medical Sciences, USSR

APPARATUS FOR RADIATION-CHEMICAL STUDIES

A. Kh. Breger, V. A. Belynsky, V. L. Karpov, S. D. Prokudin,
and V. B. Osipov

1. The general requirements pertaining to apparatus for radiochemical investigations: dosage rates, volume of irradiated material, possibility of carrying out studies in complicated physical-chemical apparatus, instruments for remote control and observation of the experimental conditions and processes which occur in the objects being studied during irradiation. Requirements for the preparation of the radioisotopes from which the high-intensity sources are fabricated.

2. K-300 and K-1400 systems of the Karpov Physicochemical Institute as stages in the development of apparatus which meets the requirements for radiochemical studies.

3. A short description of the K-20,000 system. The apparatus has a cobalt radiator with an activity of 20,000 g-equiv. Ra, and provides a dosage rate of approximately 1,000 r/sec over a volume of 0.5 liter and approximately 100 r/sec over a volume of 100 liters. Kinematic design. Form, size, and activity of the γ -radiation source. The method of assembly for the high-intensity source from standard preparations of radioactive cobalt. Safety devices and accident control. Remote control panel and observation of the physicochemical conditions in the experiment and processes which take place in the test objects during irradiation.

4. Extension of the possibilities of radiochemical studies: stronger doses, increased volume for the samples being irradiated, more complicated conditions in carrying out the experiments with the K-20,000 system.

L. Ya. Karpov Physicochemical Institute
Ministry for Chemical Industries, USSR

LABORATORY COBALT-IRRADIATOR STATION

A. V. Babushkin, I. V. Voznesenskaya, N. G. Zhirev,
V. I. Zatulovsky, and Yu. L. Khmel'nitsky

1. Possibilities for initiating and accelerating important reactions in petroleum refining and technology by the application of γ -radiation.

2. Design for a station for studying the effect of γ -radiation on petroleum products. The station will have two γ -systems with an activity up to 800 g-equiv. Ra, and one system with an activity of 10,000-16,000 g-equiv. Ra. In the first two systems the radiation sources are kept in lead containers in concrete blocks. The sample being investigated is lowered in the block after which the radiators are removed from the containers and irradiation takes place. It is expected that dosage rates of 80-90 r/sec will be achieved.

In the apparatus with 10,000-16,000 g-equiv. Ra, the radiator is kept behind a water shield and in irradiation is placed in a concrete enclosure. In the center of the cylindrical irradiator this system is expected to provide a dosage rate of approximately 500 r/sec. The irradiator is charged behind a water shield in a separate enclosure.

3. Structural form of the components of the apparatus. Shielding provisions.

All Union Scientific Research Institute for Petroleum
and Gas Refining and Production of Synthetic Liquid Fuel
Ministry of Petroleum Production, USSR

SOURCE OF IONIZING RADIATION FOR WORK IN RADIATION CHEMISTRY

V. I. Zatulovsky

1. An x-ray machine as a source of ionizing radiation for work in radiation chemistry. Requirements on the apparatus and results of work on the construction of x-ray tubes and power supplies.

2. Apparatus with radioactive cobalt for work in radiation chemistry. Characteristics and results obtained in the use of the GOP-1 and GOP-400 machines. Comparison of x-ray and cobalt systems.

3. Projected systems with Co^{60} activities of 2,500 and 10,000 g-equiv. Ra. Basic computational data and characteristics of the radiators. Construction of the machine and radiation shielding.

4. Standardization of laboratory design for sources of ionizing radiation for work in radiation chemistry.

Institute for Physical Chemistry
Academy of Sciences, USSR

DESIGN OF AN EXPERIMENTAL SEMI-INDUSTRIAL RADIATION SYSTEM
TO PREVENT GRAIN INFESTATION

E. S. Pertsovsky, A. V. Bibergal, and U. Ya. Margulis

1. One of the most novel of the peaceful uses of atomic energy is the protection of grain against insects. Laboratory studies show that grain can be freed of warehouse insect pests if it treated with a radiation dose of 10,000 r.

2. To explore the technological-economic questions involved in the industrial radiation of grain a semi-industrial device has been built with which 450 kg of grain per hour can be irradiated.

3. The system makes use of a radiator in the form of a cylinder along a generator of which is placed a rod with radioactive cobalt. The calculated activity of the radiator is 32,000 g-equiv. Ra; however the construction makes it possible to increase this figure to 100,000 g-equiv. Ra.

4. Continuous operation is achieved by using a conveyor which consists of a series of carts which are automatically loaded and unloaded.

5. An original mixed system of radiation shielding is used. When the radiator is charged and removed water shielding is used; otherwise, "dry" shielding is used.

6. It appears likely that use can be made in such industrial machines of the waste from nuclear reactors, in radiators of appropriate design (cellular).

All Union Scientific Research Institute for Grain
and Grain Products
Ministry of Agricultural Products, USSR

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All Union Scientific Research Institute for Petroleum
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All Union Scientific Research Institute for Grain
and Grain Products
Ministry of Agricultural Products, USSR

γ -IRRADIATOR FOR PRESERVATION OF FOOD PRODUCTS

N. D. Chernyaev

1. Possible forms of radiation treatment of food products and types of radiation suitable for this purpose. Different radiation sources of value for use in food technology.
 2. Technical conditions in an experimental radiator. Requirements for food processing: maximum dosage rate of the order of 2.25 fer/sec; operating volume for the dosage field of 2.5 liters; permissible inhomogeneity of the dosage field in the working volume not more than 20%; feeding of specimens under irradiation by mechanical means in the direct flux.
 3. Description of a projected design for a γ -machine for experimental irradiation of food products with different types of water shielding. The irradiator is in the form of a "squirrel cage" submerged in water in a special tank. The active material in the irradiator is metallic Co^{60} which is used in the form of rods. The separate elements are placed in an aluminum tube 1 m in length. The total activity of the radiator is of the order of 200 kg-equiv. Ra. In charging and renewing the irradiator a supplementary tank is used; this tank is connected to the operating tank in which all operations are carried out under water.
- The products being irradiated are fed on a circular conveyor which runs below ground level in a tunnel which passes through the irradiator.
4. A description of high-activity γ -irradiators built in the USA for the irradiation of food products.

All Union Scientific Research Institute for the Preservation
and Vegetable Drying Industry
Ministry for Food Supply, USSR

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ACADEMY OF SCIENCES, USSR
CENTRAL COMMITTEE ON UTILIZATION OF ATOMIC ENERGY
COUNCIL OF MINISTRIES, USSR

ALL-UNION CONFERENCE ON THE APPLICATION OF
RADIOACTIVE AND STABLE ISOTOPES IN THE
NATIONAL ECONOMY AND SCIENCE

ABSTRACTS OF PAPERS GIVEN IN THE SESSION ON
TECHNICAL SCIENCES AND INDUSTRIAL USES OF ISOTOPES

Moscow 1957

I. METALLURGY AND METAL-WORKING

THE THERMODYNAMIC ACTIVITY OF SULFUR IN LIQUID IRON

V. K. Zhuravlev and A. A. Zhukhovitsky

The present paper deals with the use of the sulfur isotope S^{34} in studies of the thermodynamic activity of sulfur in the systems Fe-S-C, Fe-S-Si and Fe-S-P as functions of temperature and the concentrations of carbon, silicon and phosphorus. Methods which have been described earlier were used in carrying out the experiments.

The sulfur concentration varied over the range 0.04-0.4% in all the systems. In each system 10 melts with different carbon, silicon and phosphorus contents were studied.

The carbon concentration in the Fe-S-C system varied over the range 0.49-5.05%. The activity coefficient of carbon then varied over the range 1.16-9.13 at 1550°, 1.13-7.6 at 1600° and 1.13-6.02 at 1650°.

In the Fe-S-Si system the silicon content varied over the range 0.85-10.45%, while the sulfur activity coefficient varied over the range 1.20-11.2 at 1560°, 1.18-9.10 at 1620° and 1.15-7.70 at 1670°.

In the Fe-S-P system the P varied over the range 2.15-15.05%, and the sulfur activity coefficient varied over the range 1.24-5.80 at 1550°, 1.23-5.05 at 1600°, 1.20-4.15 at 1675°.

From the experimental data obtained ΔH , ΔS and ΔF for sulfur were calculated.

In the system Fe-S-C, ΔH for sulfur varied over the range from 2000 to 2900 cal/g-atom, and ΔS varied over the range from 0.9-11.5 cal/g-atom.

In the system Fe-S-Si, ΔH for sulfur varied over the range 2000 to 2400 cal/g-atom, and ΔS for sulfur over the range 1.16 to 8.4 cal/g-atom °C.

In the system Fe-S-P, ΔH for sulfur varied over the range 1900-18,500 cal/g-atom, and ΔS for sulfur over the range 0.9-6.6 cal/g-atom °C. The cause of the increase in ΔH for sulfur may be that the carbon, silicon and phosphorus alter the interaction energy between the sulfur and the iron, and also that increases in the contents of carbon, silicon and phosphorus may cause the sulfur to pass from interstitial to substitutional solution. The large increase in ΔS for the sulfur cannot be explained by increase in the positional entropy, but is evidently due to increase in the entropy of vibration.

In the paper a theoretical treatment is given of the solutions of metalloids in liquid iron: for this purpose both our own experiments and the experimental studies of other workers have been used. The theory is based on the hypothesis that the dissolved substance forms both interstitial and substitutional solutions with the iron. The theory is in satisfactory agreement with the experimental data.

Theories which assume that the dissolved substance forms only interstitial solutions with the iron lead to agreement with experiment up to comparatively low concentration limits of the dissolved substances.

Stalin Steel Institute.

THE EFFECT OF SLAG STIRRING ON THE RATE OF DESULFURIZATION OF PIG IRON

V. V. Sosnin, O. V. Travin and E. N. Yarkho

In order to elucidate the rate-limiting step in the process of sulfur transfer from the pig iron to the blast-furnace type slag, the effect of mechanical mixing on the rate of desulfurization was studied.

The mixing was carried out by rotating graphite propellers in the slag at different rates at 1375° and 1500°C.

It was found that the kinetics of the process were described by an equation of first order with regard to the sulfur concentration in the metal both with and without stirring. This enables one to judge the effect of stirring from the desulfurization rate constant. It was found that the role of the stirring increased as the temperature fell. This is one indication that the process is of diffusion type.

By using radiosulfur, autoradiographs were produced which showed the accumulation of the sulfur in the slag at its contact with the metal. Microphotometry of the radiographs showed that the thickness of the diffusion layer was approximately 0.01 mm.

Central Ferrous Metallurgy
Research Institute

STUDY OF THE THERMODYNAMICS OF THE DEPHOSPHORIZATION OF PIG IRON

I. Yu. Kozhevnikov and L. A. Shvartsman

Due to the experimental difficulties, accurate values for the thermodynamic functions in the dephosphorization of iron by slags of various compositions have so far not been obtained.

By using a method in which the iron is subsequently saturated with radioactive phosphorus from the slag, it was possible to estimate the effects on the heat of reaction due to the cations and anions in the slag separately from measurements of the temperature variation of the phosphorus distribution index.

The exact value of the heat of reaction in the dephosphorization of iron by a ferrous slag was found to be 50,000 cal/g-atom. The heat of formation of $\text{Fe}_4(\text{PO}_4)_2$ from its oxides was calculated to be about 76,000 cal/g. mole.

It was found that the introduction of the ions Ca^{++} , Sr^{++} and Ba^{++} into the ferrous slag facilitated the dephosphorization due both to increases in the heat of reaction and in the entropy, which increases linearly as the concentration and radius of the metal cation increase. The effect of the entropy factor, as compared with the energy one, was greater for Sr^{++} and Ba^{++} than for Ca^{++} . It was shown that the dephosphorization capacity of the oxides of alkaline-earth metals increased with the radius of the cation. The dephosphorization capacities of FeO and MgO were comparable.

The acidic oxides (SiO_2 and P_2O_5) reduce the entropy of dephosphorization sharply if introduced into the ferrous-calcium slag. The heat of reaction increases sharply at the same time. In order to explain this, the hypothesis that the complex anions polymerize is put forward.

When both SiO_2 and P_2O_5 are present in the ferrous-lime slags at the same time, the heat of reaction is 65,000–70,000 cal/g-atom, and is practically independent of the acidic oxide concentrations. But the entropy of dephosphorization then depends materially on the SiO_2 and P_2O_5 concentrations.

It was found that the dephosphorization reaction under open-hearth conditions reached a condition approximating to equilibrium.

Central Ferrous Metallurgy Research
Institute.

MEASUREMENT OF THE TRANSPORT NUMBERS FOR IONS IN MIXTURES OF FUSED OXIDES

V. I. Malkin, S. F. Khokhlov and L. A. Shvartsman

Measurement of the transport numbers for ions in mixtures of fused oxides gives us information about the relative mobilities of the ions which is important for a deeper understanding of the structures in liquid silicates, phosphates and similar systems which are close in composition to metallurgical slags.

In the Metal Physics and Metal-working Institute of the Central Ferrous Metallurgy Research Institute, a method has been developed for determining the transport numbers of the cations in fused oxides, based on the measurement of small concentration changes. The accurate determination of such changes was realized by using Ca^{45} , Na^{24} , K^{42} as radioactive indicators.

The transport numbers of calcium ions in calcium phosphate and sodium ions in sodium silicate were determined. It was found that in such melts, the transport numbers of the cations Ca^{++} and Na^{+} were close to unity. It was found that when both calcium and sodium ions were present in the silicate melt at the same time ($\text{Na}_2\text{O} \cdot \text{CaO} \cdot 4\text{SiO}_2$) the mobility of Na^{+} was about twice as great as that of Ca^{++} .

The measurements of the transfer numbers of sodium and calcium ions in a solution of $\text{Na}_2 \cdot \text{K}_2\text{O} \cdot 4\text{SiO}_2$ showed that the mobilities of those cations are similar. At the same time, the transfer number of the potassium ion in the $\text{K}_2\text{O} \cdot \text{CaO} \cdot 4\text{SiO}_2$ melt greatly exceeds the transfer number of the calcium ion and is also greater than the transfer number of the sodium ion in the $\text{Na}_2\text{O} \cdot \text{CaO} \cdot 4\text{SiO}_2$ melt. This indicates the existence of a mutual effect between the interactions of the cations and their mobility.

In the $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{SiO}_2$ the transport number of the calcium cation falls as the Al_2O_3 : CaO ratio increases. This suggests that in the melts of this system, the aluminum may exist in cationic form, and thus may also take part in transport of the current through the slag.

Central Ferrous Metallurgy Research Institute.

STUDY OF MASS TRANSFER IN LIQUID SLAGS

F. S. Vorontsov and O. A. Esin

This report deals with a method of applying radioactive isotopes in studies on mass transfer in melts in the system $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{SiO}_2$ and $\text{FeO} \cdot \text{Fe}_2\text{O}_3 \cdot \text{SiO}_2$, these making up many blast-furnace and open-hearth

slags. Particular attention is paid here to the simultaneous use of two isotopes to study mass transfer, which is very important, due to the difficulty in reproducing the conditions of high-temperature experiments.

The results presented show that the mass transfer of sulfur in a graphite crucible occurs to a considerable extent by surface diffusion, since in this case, the crucible material wets the melt but poorly. The prior introduction of a stable sulfur isotope into the slag (about 1%) increases the wettability of the graphite and reduces the rate of sulfur diffusion by a factor of 3-4.

A further rise in the wettability, produced by using an alumina crucible, suppresses surface diffusion and reduces D_s in the blast-furnace slag.

Study of the simultaneous mass transfer of calcium and iron in a blast-furnace slag, melted in a corundum crucible, showed that the iron diffuses somewhat more rapidly than the calcium. As the temperature increased this difference became less.

The mass transfer in a fayalite melt was studied by using special thermostats filled with fused copper. The rate of simultaneous transfer of sulfur and iron appeared to be some two orders of magnitude greater than in a blast-furnace slag in these experiments, which corresponds to the difference in viscosities of these liquids. The fraction due to convective transfer in the ferrous slag was greater than in the blast-furnace slag, which equalized the apparent coefficients of diffusion for sulfur and iron.

Kirov Polytechnical Institute of the Urals.

STUDY OF THE BLAST-FURNACE PROCESS BY ISOTOPE METHODS

I. P. Bardin, P. L. Gruzin and S. V. Zemsky

Study of the blast-furnace process by isotope methods was carried out at a number of works concerned with ferrous metallurgy during 1952-6. The present report describes the results of some studies on the movement of charge materials and the wearing away of refractory linings in blast-furnace ovens.

The experiments were carried out with radioactive isotopes in a number of works, and showed that it was desirable to study and control the blast-furnace process by the new method. Application of the new method enabled us to obtain fresh data on the working of blast-furnace ovens. In particular, it was found that the different components of the charge moved at different rates. It was also shown that the main factors which control the burning away of the well are the mode of construction and the cooling system, and also the rate at which the oven is worked. Those wells were of greater durability in which the cooling was more effective, other things being equal.

Central Ferrous Metallurgy Research Institute,
Kuznets Metallurgical Combine
Magnitogorsk Metallurgical Combine
Dzerzhinsky Metallurgical Works, Novotul,
Ordzhonikidze "Azov Steel" Works.

STUDY OF THE TYPE OF MOVEMENT OF CHARGE MATERIALS IN BLAST-FURNACE OVENS

G. G. Lukashev, Ya. S. Gorbanev, L. D. Prikhodko, D. V. Gulyga
A. M. Skrebtsov and A. A. Cherepivsky

Study of the movement of charge materials in blast-furnace ovens is of importance in design of the furnace profile and in the operation of the whole blast-furnace process.

The schemes for this movement, based on the behavior of models, do not take into account effects due to a number of technological factors in the real blast-furnace process.

The difficulty of studying the movement of material in the oven is due to the blast-furnace process occurring under conditions which are inaccessible to investigation.

The use of radioactive isotopes makes it possible to follow the movements of the separate components of the charge material over the cross section and throughout the whole height of the blast-furnace oven from the charge hole to the hearth.

The measurements carried out in the present experiments were on the average rate of movement of limestone over a cross section of the furnace, and on the change in this rate with height in the furnace, and they showed that the velocity with which the limestone moved differed over the furnace cross section. The rate with which the limestone moved, was largest at the axis of the furnace. The rate of movement of the charge materials was found to be least at the periphery of the furnace.

The rate of movement of the limestone changed considerably with height in the furnace. The maximum rate was found in the upper part of the furnace.

Ordzhonikidze "Azov Steel" Works.

SOME QUESTIONS OF METHODOLOGY IN DETERMINING THE BURN-UP OF THE WELL IN A BLAST-FURNACE OVEN

A. M. Skrebtsov, A. A. Cherepivsky and G. D. Muguev

In principle, there are two possible ways of using radioactive isotopes to study well burn-up:

- 1) including radioactive isotopes in the various layers of the refractory lining of the well upon major repair;
- 2) periodic determination of the volume of the "pocket" in the furnace by isotope dilution methods, by inserting an isotopic tracer in the pig iron.

The work was carried out in the second way. The phosphorus isotope used was introduced into the hearth in three ways:

- 1) in eight iron ampules, via the furnace hopper;
- 2) in a limestone ampule at level 31,455;
- 3) in an iron ampule via a port.

The first method gives the most uniform isotope distribution over the volume of metal present in the hearth.

A formula is derived for determining the volume of the "space" in the hearth. Relations between the average computed amount of pig iron in the hearth space and the silicon content in the metal were found.

It was found that in order to label the iron in the hearth uniformly, it was desirable to introduce the radioactive isotope in several ampules via the feed apparatus on the oven. It was shown that the mixing of the pig iron in the well of the blast-furnace oven became greater as the temperature rose, which may be estimated indirectly via the silicon content of the pig iron.

Ordzhonikidze "Azov Steel"
Works.

STUDY OF THE KINETICS OF SCRAP FUSION IN THE SCRAP-ORE PROCESS

A. I. Osipov, L. A. Shvartsman, V. I. Alekseev, V. F. Surov, M. L. Sazonov,
M. T. Bulsky, S. A. Telesov, A. M. Skrebtsov, A. M. Ofengenden,
F. F. Sviridenko and L. G. Goldshtein

The fusion of the solid metal charge in open-hearth ovens takes up a considerable part of the whole time required for fusion. The development of technological methods capable of reducing the time required for fusion must be based on correct theories of the charge fusion mechanism.

Radioactive cobalt has been used at the "Azov Steel" and Stalinsk metallurgical works (Donbass) to determine the rate of fusion of the scrap in the scrap-ore process; this being introduced into the ladle car while it is being filled with pig iron from the mixer.

The weight of the fused scrap at each instant was determined as the difference between the weight of the fused metal in the hearth, calculated from the specific activity of the metal via a test specimen, and the weight of the fused pig iron present in the furnace at that moment. Account was taken of the amount of impurities in the crude iron which had been oxidized. Thus, the kinetics of fusion of the scrap were studied in the scrap-ore process in 350- and 130-ton open-hearth ovens. It was found that the rate of this process, dx/dt , is described satisfactorily by the following simple kinetic equation:

$$\frac{dx}{dt} = K_F (100 - x)^{-1/4}.$$

The rate constant for the fusion of the scrap, K_F , is an objective criterion for the rate of fusion. This makes it possible to establish a quantitative relation between the various technological factors and the rate of fusion.

In addition, when the value of K_F is known for a given melt, it is easy to compute the amount of scrap which has melted at a given instant and the true rate of oxidation of impurities during the fusion. It was shown that the rate of fusion of scrap increases almost linearly on increasing the heat loadings. Under the conditions found at the "Azov Steel" works, the rate of fusion depended materially on the period taken to pour the pig iron in. Shortening of this operation can lead to an increased rate of fusion and a reduction in duration of the melting.

The rate of fusion of the scrap depends appreciably on the amount of carbon in the vat. Increase in the rate of oxidation of the carbon also leads to an increased rate of fusion.

Ordzhonikidze "Azov Steel" Works.
Central Ferrous Metallurgy Research Institute.

STUDY OF THE RATE OF FUSION OF SCRAP IN THE OPEN-HEARTH FURNACE IN THE SCRAP-ORE PROCESS

A. N. Morozov, A. I. Stroganov, O. Ya. Vainshtein and V. F. Isaev

The period in the open-hearth furnace which has been the least studied is that of fusion, which is due in the main, to the complexity of study during this period. Radioactive isotopes can be of considerable help in this connection.

The present study was concerned with the fusion of the charge in a 370-ton open-hearth furnace operating in the scrap-ore process with 65% pig iron and heated by the gas from metallurgical coke. The radioactive Co^{60} was introduced with the crude iron before it was poured into the furnace, while the P^{32} was placed in the lower layer of the iron ore. From the fall in the radioactivity of a test specimen during the fusion process, the rate of fusion of scrap was determined, and from the appearance of P^{32} in the slag, the instant when the ore ceased to react with the pig iron was judged. Three melts were carried out.

The study showed that the main mass of scrap (about 70%) melts in the first hour after pouring in the pig iron. The mechanism of scrap fusion consists in its prior carbonization, by the pig iron. The fall in the carbon content at the beginning of fusion is in the main, due to dilution of the pig by the scrap. The rate of carbon burn-out from the scrap reaches a maximum during the time that the later portions of scrap are reacting with the pig iron. The phosphorus content in the metal is also a minimum at this time.

Thus, the main processes which occur during the time of fusion are: fusion of scrap, dephosphorization and carbon burn-up, these being closely related.

Chelyabinsk Polytechnical Institute.
Chelyabinsk Metallurgical works.

STUDY OF THE KINETICS OF THE PROCESS OF SLAG FORMATION IN MELTS IN OPEN-HEARTH FURNACES

L. A. Shvartsman, A. I. Osipov, V. I. Alekseev, V. F. Surov, M. L. Sazonov
M. T. Bulsky, S. A. Telesov, A. M. Skrebtsov, A. M. Ofengenden,
F. F. Sviridenko and L. G. Goldshtein

The study of the conditions under which slag forms during the initial period of fusion is an important practical task.

Data on the course of the process of slag formation can be obtained by determining the rate of solution of calcium oxide (limestone) placed at the bottom of the open-hearth furnace. But the determination of this rate by chemical analysis of test specimens for their calcium oxide contents produces ambiguous results, as oxidation of impurities in the pig iron and fusion of the scrap occur at the same time as solution of limestone. In addition, the methods of chemical analysis do not make it possible to determine in which zone the process of slag formation begins.

The use of radioactive indicators enables us to label various sections of the materials which give rise to the slag and, taken in conjunction with methods of chemical analysis, make it possible to study the features of the slag formation process. Such a study is capable of elucidating the conditions under which the slag formation process can be accelerated, and thus, also, the rate of production of molten steel.

In the present work, radioactive calcium was used to determine the weight of the slag in the furnace, and thus, to estimate the rate of solution of calcium oxide from the limestone in the slag.

It was found that the kinetics of solution of calcium oxide are described satisfactorily by the same equation as in the solution of scrap, namely:

$$\frac{dx}{dt} = K_s (100 - x)^{1/2}$$

The constancy of K_s in each melt enables one to use this quantity to estimate the rate of the slag formation process. It was found that the relation between the K_s and the rate constants for the fusion of scrap, determined on the same melts, was regular. The presence of such a relation is a reflection of the physicochemical conditions which determine the courses of both processes as being the same - i. e., fusion of scrap and solution of lime.

The magnitude of the slag formation constant (K_s) increases on increasing the heat loading and reducing the period taken to pour in the pig iron.

The increase in the slag-formation constant leads to an increase in the average rate of dephosphorization during the fusion process.

Central Ferrous Metallurgy Research Institute,
Ordzhonikidze "Azov Steel" Works,
Stalin Metallurgical works, Stalinsk.

EFFECT OF RESIDUAL SLAG FROM THE PREVIOUS MELT ON THE DEPHOSPHORIZATION IN TIPPING SIEMENS-MARTIN FURNACES

A. M. Skrebtsov, F. F. Sviridenko, M. L. Sazonov, M. T. Bulsky,
A. I. Osipov and A. G. Alimov

The functioning of high-load furnaces was studied at "Azov Steel" works under conditions where high-phosphorus ions are being reworked. The work was carried out with radioactive phosphorus, P^{32} . The isotope was introduced into the furnace at 0.5-1 hour before tapping off the metal, an even distribution of the isotope over the whole volume of the slag remaining in the furnace being attained. The weight of the residual slag was determined from a measurement of the activity, account being taken of the distribution of the radioactive phosphorus between the metal and the slag. From the increase in the count rate, due to the radiation from the phosphorus in the slag specimens, which were taken at the subsequent melt after pouring in the crude iron, the course taken by the mixing of the residual slag, and its reaction with the iron, was determined. The removal of the phosphorus from the iron was determined by chemical analysis of the slag and of the iron.

The following facts were established:

- As the amount of residual slag in the furnace increases, and also as the amount of fluidized residual slag during the initial period increases, the rate of dephosphorization rises noticeably;
- the effect of the residual slag on the oxidation of the phosphorus when high-carbon steel is reworked is more marked than in the case of low-carbon steel.

The practical deduction that can be made from this work is that in order to increase the rate of oxidation of the phosphorus during the melting, and in order to economize in the slag-forming materials, it is necessary to alternate low- and high-carbon steels.

Central Ferrous Metallurgy Research Institute,
Ordzhonikidze "Azov Steel" Works.

STUDY OF THE EFFECT DUE TO ORDER OF CHARGE FEEDS ON THE RATE OF OXIDATION OF PHOSPHORUS

F. F. Sviridenko, A. M. Skrebtsov, M. L. Sazonov, M. T. Bulsky
and A. I. Osipov

The process of oxidation of phosphorus during and open-hearth fusion is an extremely important factor which determines the time required in the melt and the quality of the molten steel, under the conditions found in the "Azov Steel" Works. The study of the behavior of phosphorus in the furnace and the working out of a technique for removing it from the metal is of considerable interest. The interaction of layers of charge fines (ores and limestone) with the crude iron which is poured in was studied, as well as its connection with the dephosphorization of the metal. Radioactive isotopes used in the experiments were of phosphorus, calcium, Ca^{45} and cobalt.

A method was developed of assaying the radiations from the radioactive isotopes of phosphorus and calcium separately when they were present at the same time in slag specimens.

The following facts were established:

- The oxidation of phosphorus occurs more rapidly when a large part of the ore is placed above the limestone;
- The ore reacts with the crude iron earlier than does the limestone placed above it;
- The uppermost layer of the charge reacts with the crude iron as soon as it is poured in.

The following recommendation is derived from the work: in order to speed up the removal of phosphorus from the metal, a part of the ore in the charge should be placed above the limestone.

Central Ferrous Metallurgy Research Institute,
Ordzhonikidze "Azov Steel" Works.

THE PROCESS OF FUSION OF IRON ORE WITH LIMESTONE, AND THE ORDER IN WHICH THEY ARE CHARGED IN OPEN-HEARTH FURNACES OF HIGH CAPACITY

V. F. Agapov, A. P. Varshavsky and A. I. Lyakonov

The melting period is the longest part of the open-hearth process. The aim of the present work was to study the succession and the rates of fusion in the various zones of the charge materials with the aid of radioactive isotopes, and also to establish the order of charging the iron ore and limestone which was most advantageous under the conditions found in the Magnitogorsk Metallurgical combine, in order to increase the throughput of the high-capacity open-hearth furnaces.

The preparations, which contained the radioactive isotopes of sulfur, phosphorus and iron, were mixed with pieces of iron ore and limestone which were loaded into the open-hearth furnace in the various layers of the charge materials. The moment when radioactive material appeared in specimens of slag and metal taken during the melting showed when the labeled pieces of charge were consumed, and the corresponding layers of the furnace lining went over to the fused state.

The experimental data gave rise to the following conclusions.

The melting of the nonmetallic charge in the open-hearth melt begins in practice at the instant when the crude iron is poured in, and passes gradually from the upper layers to the lower ones. The deeper the charge layers, the later their fusion was completed. The top layers of the charge materials melt first, these being directly under the scrap, and then the ore layers (placed at the bottom). Fusion of the lower layer, in fact, indicates the end of the fusion of the nonmetallic charge.

The gradual course of the fusion of the charge materials, passing from top to bottom after the crude iron has been poured in, shows that the crude iron does not reach the lowest lying layer of the charge, at once, in an active state, but begins to work through the ore and limestone layer by layer.

The mean rate of melt-down in the nonmetallic charge of 380-ton open-hearth furnaces at the Magnitogorsk Metallurgical combine is about 220 mm/hour at the bottom of the well.

The duration of the melting of the lining materials is found to be shortest when the lining has the minimum amount of iron ore at the bottom, with a deeper layer of limestone divided with a layer of iron ore, and with a uniform layer of the remaining ore as the top layer.

Such an order of loading of the lining materials was adopted in the works after the present work had been performed.

Magnitogorsk Metallurgical combine.

MEASUREMENT OF THE SULFUR CONTENT IN METAL, SLAG AND PRODUCTS OF COMBUSTION DURING THE OPERATION OF 380-TON OPEN-HEARTH FURNACES

P. N. Perchatkin

The study of the reaction between the sulfur in the fuel and the charge material was carried out on experimental melts, radioactive sulfur being inserted in the liquid crude iron (the amount of isotope used was about 3 μ C/ton) and in the fuel (the amount of isotope used was 2870 μ C/mel). In order to determine the radioactive content of the metal, slag and combustion products, the sulfur was worked up into the form of barium sulfate.

Analysis of the experimental melts showed that on firing the furnace with sulfurous fuel, the sulfur was absorbed by the charge materials, by the metal and by the slag from the gas phase in the furnace. On using petroleum residues at rates up to 1400 Kg/hr (up to 40% of the total fuel requirement in heat content) the products of the melt contained 9-14% more sulfur than was present in the charge materials, while on firing the furnace with a gas mixture only the sulfur content in the melt products, due to its oxidation and removal in the gas phase, was 8-10% less than in the charge materials.

The greatest absorption of sulfur from the gas phase by metal and slag occurred while the scrap was being heated and melted. While the charge was being heated, the sulfur was absorbed by the thin layer of iron oxides which covers the scrap. During the period of fusion, the agents which transfer the sulfur from the gas phase to the metal are beads of iron in the slag. The radioactivity of barium sulfate prepared from the iron beads when the isotope was inserted in the fuel exceeds that of the barium sulfate prepared from the metal and slag, and is close to that of the combustion products. The iron beads are also active in transferring sulfur from the metal to the slag. When the sulfur content of the combustion products is higher, the iron beads can saturate the metal with sulfur.

The change in the radioactivity of the slag during the first half of the fusion period corresponded with the changes in the sulfur content of the slag when the radioactive sulfur was introduced with the fuel.

In addition to the absorption of sulfur from the gas phase by the metal and slag, when the furnace was fired with sulfur-bearing fuel, part of the sulfur in metal and slag was also oxidized during the various periods, and was removed as sulfur dioxide from the oven. The gas phase from a Siemens-Martin furnace carries off sulfur at once, after pouring of the crude iron, since the sulfur in the crude iron is oxidized by the oxygen in the gas, and to a great extent by the primary slag, which contains much iron, as well as on blowing the open-hearth furnace vigorously after adding the iron ore at the end of melting. During this period of the operation, the radioactivity of the combustion products was observed to be raised when the radioactive sulfur was introduced into the open-hearth converter.

When the radioactive sulfur was introduced along with the fuel, it was found that it was deposited in the stack, and that it circulated in the oven system for a long while, before being lost.

Nosov Institute of Ferrous Metallurgy, Magnitogorsk.

DEVELOPMENT OF A METHOD OF DETERMINING THE WEIGHT OF STEEL IN A STEEL-POURING LADLE

A. I. Ofengenden and L. G. Goldshtein

Radioactive isotopes were used in order to determine the weight of steel in a steel-pouring conveyor. The weight of the metal in the crucible was determined from the formula

$$G = K \cdot \frac{I_{Co}}{I_s}$$

where G is the weight of the radioactive isotope inserted in the metal; I_s is the activity of a standard specimen; I_{Co} is the input activity of the radioactive metal isotope; K is a constant of proportionality.

The experimental melts were carried out in steel-pouring crucibles of capacity 130-140 tons.

The isotopes P^{32} , Co^{60} and Ir^{192} were used, these being introduced at the time when the melt was tapped off. The experiments showed that radioactive phosphorus, like any other element which becomes oxidized and enters the slag, cannot be used to determine the amount of metal in the crucible. Radioactive iridium and cobalt can be used to determine the amount of metal in the crucible. The mean error with which the amount of metal in the crucible was determined was 2%. The maximum error did not exceed 3.3%.

Stalin Metallurgical works, Stalinsk.

STUDY OF THE CONTAMINATION OF STEEL BY OXIDE INCLUSIONS DUE TO SECONDARY OXIDATION DURING TAPPING AND POURING OUT

E. I. Malinovsky and A. N. Morozov

The studies were carried out under production conditions on ball-bearing steel. The steel was melted down in 40-ton ovens and decanted as billets of weight 2.65 tons, by the syphon method.

We first studied the effects due to the refractory materials in the crucible and the syphon tube, and due to the slag in the contamination of the steel by oxide inclusions. The refractories were labeled with radioactive calcium.

It was found that the refractory materials were without effect on the contamination of the steel by non-metallic inclusions.

Secondly, the effect of secondary oxidation on the formation of oxide inclusions in the steel was studied. Zr^{90} and Ta^{182} were used as the radioactive indicators, these being introduced into the completely deoxygenated metal not long before tapping off.

Specimens of metal taken from the furnace, the ladle and the drawn iron were dissolved by electrolysis and used for radiometric analysis.

It was found that the zirconium, which became oxidized during the tapping off operation, was removed fairly completely from the metal, although the oxidation products from zirconium appear in the liquid steel as very fine solid particles, like particles of alumina. On the other hand, zirconium which became oxidized during the pouring-off and crystallization of the steel, remained in it to a considerable extent, thus contaminating it with inclusions.

The behavior of tantalum, which has a much weaker deoxidant action, differs essentially from that of zirconium. A considerable amount of the tantalum is removed from the metal during the tap-off time. The tantalum is also oxidized during pouring, and almost all the tantalum which becomes oxidized is removed from the metal, which is evidently explained by the formation of oxidation products which are readily fusible.

Chelyabinsk Metallurgical works,
Chelyabinsk Polytechnical Institute.

STUDY OF THE NATURE OF SLAG INCLUSIONS IN BILLETS AND REROLLED SHEET MILD STEEL

D. S. Gerchirov, A. I. Ofengenden and L. G. Goldshtein

The radioactive isotope Ca^{45} was used to study the nature of non-metallic inclusions in air-blown steel. The experiments presented show that slag, formed on the surface of the metal in the mold and retained, plays an important part in the formation of non-metallic inclusions in air-blown steel.

These slag contaminants, which are sometimes present down to large depths in the casting, can be reduced by increasing the carbon content of the metal, thus causing it to bubble less intensely in the mold.

The slag may be formed by destruction of the syphon walls by the metal on tapping-off, but the main source of slag formation is the products of self-deoxidation in the mold.

The formation of non-metallic inclusions can be reduced by removing the slag mechanically with a paddle from the bubbling metal, and by the use of fluxes to liquify the slag.

It is also to be recommended that the metal be tapped off at a moderate temperature.

Stalin Metallurgical works, Stalinsk.

RATE AND SEQUENCE IN THE CRYSTALLIZATION OF INGOTS OF BUBBLE-FREE STEEL

M. I. Kolosov, A. N. Morozov, A. I. Stroganov, V. F. Isaev
N. V. Keis and O. Ya. Vainshtein

Study of the mechanism and rate of solidification of billets is of great theoretical and practical interest. In the present work, the sequence of crystallization in various billets was studied by different methods: by tilting the molds, by the temperature changes in the steel and by radioactive tracer methods. Fe^{59} was used as the radioactive tracer. Billets of weight 2.86, 5.5 and 6.2 tons, made of steel types ShKh15SG, 10, 45 and 30KhGT were studied. The billets were run in, via a siphon. From these studies, it was found that after the acicular crystals on the side faces had ceased to grow, a two-phase region at a depth of 30-50 mm was formed on the side faces, while a two-phase region at depths down to 850 mm was formed in the central part.

The thickness of the solidified layer in a horizontal section was proportional to the square root of the time of crystallization during the initial phase of crystallization. The coefficient of proportionality was 21-29 mm/min^{1/2} for carbon steel, and fell on reducing the carbon content of the steel.

Chelyabinsk Metallurgical works,
Chelyabinsk Polytechnical Institute.

STUDY OF IMPURITY DISTRIBUTION IN THE CRYSTALLIZATION OF STEEL

V. M. Tageev and Yu. D. Smirnov

This paper gives the results of experiments connected with the study of the action of rare-earth metal alloys (those of cerium, lanthanum and zirconium) on the distribution of impurities in the crystallization of steel.

Since the corresponding action on liquid steel ensures the removal of sulfur from solution as a disperse sulfide phase at an early stage in the crystallization, there will be a marked reduction in its tendency to accumulate by diffusion at grain boundaries, and thus, for impurities to accumulate in the form of zones of nonuniformity ("whiskers" etc.).

The addition of 0.05-0.2% of an alloy of the rare-earth metals to the deoxidized steel causes an increase in the plasticity (ϵ , ϕ) and impact viscosity (Q_k) of the steel in the cast heat-treated state, the rise being larger, the greater the amount added. This improves these properties of the metal in thick sections of the billets (castings) which is of particular importance. The addition of 0.05-0.1% of an alloy of the rare-earth metals reduces the zonal nonuniformity of billets and castings. The same addition of 0.15-0.20% practically prevents the accumulation of impurities (carbon, sulfur, phosphorus, tungsten, etc.), particularly in the form of "whiskers." Part of the sulfide inclusions are then trapped in the axes of the dendrites (the sulfides become distributed in the interaxial spaces of the dendrites in steel which has no additions). Ce^{141} becomes distributed in a manner analogous to sulfur, and is eliminated in the crystallization process as sulfide inclusions. Part of the sulfides of the rare-earth elements formed, which are of low solubility, are eliminated and float on the liquid metal. It was found that the floating sulfide phase was enriched in phosphorus and carbon. This effect is of adsorption type.

On introducing SiZr into deoxidized medium-carbon steel, the intra-axial nonuniformities ("whiskers") in the billet (casting) become markedly more prominent. Zr⁹⁰ then becomes distributed in the axes of the dendrites in the form of inclusions while the sulfides are distributed normally (in the intra-axial spaces). Zr⁹⁰ is not observed to accumulate in the places where the sulfides do. Consequently, zirconium forms oxygen-like inclusions.

The results of this work demonstrate a concrete way of developing an industrial method of reducing the nonuniformities and improving the mechanical properties of cast steel.

SOME QUESTIONS OF INDUSTRIAL HYGIENE WHERE RADIOACTIVE ISOTOPES ARE USED IN FERROUS METALLURGY

N. I. Volkova

The industrial use of radioactive tracers in ferrous metallurgy undertakings involves their introduction into metal or slag as well as the possibility that considerable numbers of workers may come into contact with them. The Industrial Hygiene and Occupational Diseases Institute of the USSR Academy of Medical Sciences has undertaken a study of the hazards when the isotopes Co^{60} , Ca^{45} and P^{32} are used in open-hearth furnaces. It was found that the preparatory operations are the most hazardous (preparation of active mixtures, unpacking of isotopes). These operations require special protective measures. A radical measure which renders these operations safe, involves use of special central laboratories at the undertakings. The planning and equipment of such laboratories must ensure that all operations in which there is a hazard of atmospheric contamination with radioactive dust and gas are conducted in closed systems, that the spread of radioactive contamination is prevented, and that shielding against external radiation is provided. In order that the transport of the radioactive isotopes from the

laboratory to the plant shall be without hazard, it is necessary to comply with special requirements as regards the construction of ampoules and containers, and as regards the conduct of this operation. Directly after the radioactive isotopes have been inserted in the metal or slag in the open-hearth plant, there is a possibility of external radiation from the metal or slag and of airborne contamination from radioactive dust. The degree of the hazard is determined by the type of radiation emitted by the isotope used, and by the specific activity of the metal or slag. The studies carried out showed that when the specific activity of the metal was about 0.2-0.3 mc/ton in the isotopes Ca^{45} and P^{32} , the level of radioactive contamination of the plant and air in the open-hearth furnaces and in the area when the slag was broken up, was considerably below the permissible limit. If the level of activity used were to be increased, this safety would be impaired. The use of long-lived radioactive isotopes may lead to the accumulation of radioactive contamination in the plant. There is also a hazard in later uses of the slag and metal which contain the added radioactive substances. According to the figures calculated, the metal Co^{60} content of 0.1-0.2 mc/ton may be the cause of the γ -ray intensity amounting to 0.2 $\mu\text{C/Kg}$ (under the worst conditions) from this metal. The mechanical working of the metal and the crushing of the slag, both containing radioactive material, may be accompanied by atmospheric contamination with radioactive dust. In order to reduce the hazard from the radioactive metal, it is necessary to store it before use for 6-10 half-lives, to label it and to restrict its later uses.

Industrial Hygiene and Occupational Diseases Institute
Of the Academy of Medical Sciences, USSR.

APPLICATION OF MICRO-AUTORADIOGRAPHY TO THE STUDY OF THE FLOTATION PROCESS

I. N. Plaksin, S. P. Zaitseva, G. A. Myasnikova, L. P. Starchik,
V. I. Tyurinkova and R. Sh. Shafeev

An autoradiographic method was used in the flotation studies in order to determine the type of reagent distribution over the surfaces, this being first used on sections.

Several methods for micro-autoradiographic study of particles of flotation size were developed and applied at the USSR Academy of Sciences Mining Institute.

1. The method of "platelets" was as follows. The mineral powder was treated with a labeled reagent, after which it was washed until the β -ray intensity was steady. An image of the radioactive isotope distribution was obtained on a β -sensitive photographic plate. The developed silver grains were photographed by transmitted light, the mineral particles being taken by reflected light. The photographs so obtained could be used to judge the type of reagent distribution over the surface structure.

2. In order to study the distribution of flotation reagents between the minerals in a slime, we used the method of counting the groups of reduced silver grains produced in a liquefied nuclear emulsion which had had the mineral particles, previously treated with the labeled reagent, stirred into it. This method was used for studying the distribution of butyl xanthogenate on the surfaces of galena particles from various fractions of the foam and nonfoam product.

3. By using a method involving transfer of thin emulsion layers directly onto the mineral particles, the resolving power was increased. This method was used to study how lime acted in the flotation of pyrites and galena: it showed that the precipitation found with lime was not only due to attachment of the anion (hydroxyl) but also to attachment of the calcium cation, which explains the high efficiency of lime as a precipitant, as compared with caustic soda.

4. Still greater sensitivity and resolving power were obtained by "wet autoradiography." In this method a very thin layer (about 1μ thick) of a highly sensitive emulsion was transferred to the mineral surface. This method was used to study the effects of oxygen on the flotation of sulfide minerals. The flotation experiments were carried out in an argon atmosphere with a known oxygen tension in the slime. The micro-autoradiographs obtained with mineral particles taken from the foam and nonfoam products showed that the adsorption of the selective agent on the mineral was determined by the amount of oxygen in the slime. The results obtained were in good agreement with activity assays.

The autoradiograms are given in the report; these show the results from the experiments using each method of micro-autoradiography as a visible record of the results.

USSR Academy of Sciences Mining Institute

STUDY OF THE INTERACTION OF FLOTATION REAGENTS WITH THE SURFACES OF SOME MINERALS

S. I. Polkin

This paper gives a short account of results obtained from the study of the interaction of iron, calcium and tin salts, as well as sodium oleate and tridecylate, with the surfaces of the following nonsulfide minerals: cassiterite, quartz, zircon, pyrochlore, ilmeno-rutile, beryl, hematite, feldspar, etc. Hematite has a much greater adsorptive and chemical activity than cassiterite and a number of other minerals; the amounts of iron, tin, and sodium oleate attaching themselves to hematite are some 10-15 times greater than for cassiterite. Conditions which favor the formation of iron oleates in the slime lead to a cessation of cassiterite and hematite flotation.

Tin ions in small amounts interact selectively with cassiterite surfaces and activate them, while excess of tin ions facilitates the formation of tin oleates, preventing the cassiterite becoming hydrophobic, and thus preventing its flotation.

Attachment of calcium to the cassiterite and quartz and the trace formation of calcium oleate (analogous to the oleates of copper, lead, iron, etc.) in the slime, reduces the recovery of cassiterite sharply.

The attachment of iron to pyrochlore, ilmeno-rutile and zircon, as in the case of hematite and cassiterite, is a maximum in weakly acid and neutral media. Powders of beryl, actinolite, muscovite, albite and quartz, previously activated by iron, undergo more satisfactory flotation when the maximum amount of iron is attached to them, but the selectivity among these is then much reduced. Only the bound part of the iron activates the flotation of the minerals. The unbound part reacts vigorously with the sodium oleate in the body of the slime, forming iron mono- di- and tri-oleates, which are not bound to the mineral surfaces and do not exert a selective action.

When iron has previously been bound to the mineral surfaces (with the aim of increasing the selectivity of flotation) the agents studied split up into two series: for pyrochlore and zircon—soda, water glass, caustic soda, sodium phosphate, sodium fluoride; for ilmeno-rutile—soda, water glass, caustic soda, sodium fluoride, sodium phosphate.

By radiographic methods, it was possible to determine in the main, the isolated uneven binding of iron, tin, calcium and tridecylate to the mineral surfaces. The results obtained were used to make a number of theoretical generalizations as to the mechanism whereby the reagents studied interact with the surfaces of nonsulfide minerals in slime flotation conditions, and to make some recommendations as to ways of counteracting the action of iron and calcium on the flotation of ores.

Kalinin Institute of Nonferrous Metals and Gold, Moscow.

ADSORPTION OF DIETHYLDITHIOPHOSPHATE AND BUTYL XANTHOGENATE ON THE SURFACES OF SULFIDES IN AN ACID MEDIUM

S. I. Mitrofanov and V. G. Kushnikova

The majority of studies on the adsorption of selective agents on heavy metal sulfides have been made in alkaline solutions.

The region of $\text{pH} < 7$ has been little studied.

In this paper the adsorption of P^{32} -labeled diethyldithiophosphate and of S^{35} -labeled butyl xanthogenate was studied, the minerals being chalcocopyrite, pyrite, sphalerite and (partially) galena, the range being $\text{pH} = 2$ to 12; effects on the adsorption due to the sulfates of copper, iron and zinc, of thiosulfite, sulfite and ferrocyanide.

The following results were obtained.

1. The adsorption of diethyldithiophosphate on pyrite, chalcocopyrite, galena and zinc-activated blend increased sharply in acid media.

The adsorption curves for diethyldithiophosphate were made up of two straight-line sections, which satisfy the equation $G = a - c \text{ pH}$. The pH at the point where the two straight lines intersected was different for each minimum, and bore a certain relation to the order of pH at which hydrolysis of the heavy metal sulfates begins, or that at which the metal hydroxides begin to precipitate. At $\text{pH} \approx 5.5$ there was a marked selectivity of adsorption of diethyldithiophosphate on chalcocopyrite. The action of diethyldithiophosphate, being in accordance with the equation $G = a - c \text{ pH}$, may be considered as exchange adsorption in the hydrolysis region, in alkaline media with the OH^- ion, and in acid media with the HS^- ion.

2. The studies on electrolytes as regards the depression effect show that they can be arranged in the following series for each mineral:

Chalcocopyrite
 $\text{K}_4\text{Fe}(\text{CN})_6 > \text{Na}_2\text{S}_2\text{O}_3 > \text{Fe}_2(\text{SO}_4)_3 > \text{FeSO}_4 > \text{Na}_2\text{SO}_3 > \text{ZnSO}_4$

Pyrite
 $\text{K}_4\text{Fe}(\text{CN})_6 > \text{Na}_2\text{S}_2\text{O}_3 > \text{FeSO}_4 > \text{Na}_2\text{SO}_3 > \text{ZnSO}_4$

Sphalerite
 $\text{Na}_2\text{S}_2\text{O}_3 > \text{K}_4\text{Fe}(\text{CN})_6 > \text{Fe}_2(\text{SO}_4)_3 > \text{FeSO}_4 > \text{Na}_2\text{SO}_3 > \text{ZnSO}_4$

But at $\text{pH} < 5$ for $\text{Fe}_2(\text{SO}_4)_3$, $\text{pH} < 6.5$ for $\text{Na}_2\text{S}_2\text{O}_3$, $\text{pH} < 8$ for ZnSO_4 , these salts do not reduce, but conversely, increase the adsorptivity of sphalerite: $\text{Fe}_2(\text{SO}_4)_3$ acts analogously with pyrite at $\text{pH} < 5$. Copper sulfate increases the adsorptivity of sphalerite at all pH values, and the adsorption curves for chalcocopyrite and pyrite have maxima at $\text{pH} \approx 5$.

3. The adsorption curves for butyl xanthogenate on the sulfides have maxima at $\text{pH} \approx 4.5$, and the adsorption falls off in accordance with equation $G = a - b \text{ pH}$ both in alkaline and in acid media. The fall of adsorptivity in acid media is due to the instability and decomposition of xanthogenic acid. The effect of electrolytes on the adsorptivity of butyl xanthogenate on the sulfides is different from that for diethyldithiophosphate:

- ferrocyanide does not depress pyrite: the selective adsorption on chalcocopyrite and sphalerite is most sharply developed at $\text{pH} = 2$;
 - thiosulfate depresses chalcocopyrite more strongly than pyrite and sphalerite;
 - sodium sulfide has the highest selective action in alkaline media;
 - the sulfates of iron, zinc and copper depress the adsorption of butyl xanthogenate on chalcocopyrite.
- The results obtained may be used to develop processes of selective sulfide flotation in acid media.

Nonferrous Metals Research Institute.

IMPURITY DISTRIBUTIONS IN THE PROCESSES USED TO PRODUCE MOLYBDATE AND PARATUNGSTATE

K. G. Koneva and S. L. Savalsky

These studies were undertaken in connection with the need to produce tungsten and molybdenum oxides of high purity, to contain 99.98% WO_3 and MoO_3 .

In order to make the particularly pure tungsten and molybdenum, the usual technical operations were supplemented by a number of steps which increase the purity of the solutions and ensure products of high purity. The contents of elements such as tin, lead, cadmium and antimony in these products did not exceed 0.0001%, while the contents of elements such as copper, iron, aluminum, magnesium, zinc, phosphorus, arsenic and sulfur did not exceed 0.001%.

However, the physicochemical behavior of the impurities and their distribution in the various stages of the technical processes had not been adequately studied. Hence, the aim of the present work was to study the physicochemical behavior of the impurities in the production of ammonium molybdate and paratungstate. Radioisotope methods were used for this purpose.

The distributions of lead, copper, tin, antimony, iron, zinc, arsenic, phosphorus and sulfur were studied under laboratory conditions in the production of ammonium molybdate and paratungstate.

It was found that the physicochemical properties of these impurities as regards the production of ammonium molybdate by the ammonia method would be divided into three groups.

The first group (lead and copper) is precipitated by ammonium sulfide.

The second group (antimony, tin, iron and zinc) remains in the acid mother-liquor after neutralization of the ammonium molybdate solution with hydrochloric acid.

The third group (phosphorus, arsenic and tungsten) can be removed in ammoniacal solutions.

In production of ammonium paratungstate, the impurities studied could be divided into two groups.

The first group was comprised of tin, zinc, iron and sulfur, which go over into the used acid after decomposing the artificial scheelite with hydrochloric acid.

Phosphorus and arsenic fall in the second group, these remaining in the mother liquors on evaporation of the ammonium tungstate solutions to obtain the paratungstate.

It was found possible to remove the large amounts of antimony present in the tungsten acid only after transforming the latter to ammonium paratungstate, subsequently decomposing this with hydrochloric acid containing a small amount of tartaric acid.

The studies presented enable one to estimate the utility of each operation in the processes proposed for obtaining particularly pure products.

North Caucasus Ferrous Metallurgy Institute.

STUDY OF THE BEHAVIOR OF THALLIUM IN THE PROCESS OF PURIFYING SOLUTIONS FROM IRON AND ARSENIC

M. A. Vinogradova, M. N. Shashkova and G. S. Rozhavsky

The hydrolytic method of purifying zinc solutions from iron, arsenic and antimony has been applied in the hydrometallurgy of zinc during recent years, atmospheric oxygen being used as the oxidizing agent.

The use of this method for purifying solutions obtained by working up lead-zinc industrial dusts which contain thallium requires that the behavior of this latter in the iron-arsenic purification be studied.

The investigations undertaken gave the following results.

1. Under conditions where the solutions are freed hydrolytically from iron and arsenic using atmospheric oxygen, the oxidation $Fe^{2+} \rightarrow Fe^{3+}$ and the precipitation of iron as $Fe(OH)_3$ do not occur even when there is much copper in the solutions.

2. The formation of thallium arsenates such as Tl_3AsO_4 and Tl_3AsO_3 only occurs to a slight extent.

3. The main process resulting in the precipitation of thallium with the $Fe-As_2$ is that of thallium adsorption on basic salts and on the hydrated arsenates and arsenites of iron and copper. The arsenates of iron and copper have the greatest adsorptivity, while the arsenites have the least. The adsorptivity of thallium increases with the pH and the thallium content of the solution.

4. Study of the thallium adsorption kinetics and of the temperature factor enables one to suppose that the adsorption of thallium on the above compounds is of physical type.

Nonferrous Metals Research Institute.

STUDY OF THE EFFECT OF SOME LIQUID-PHASE COMPONENTS ON THE RATE OF SOLUTION OF GOLD AND SILVER IN CYANIDE SOLUTIONS

I. N. Plaksin and M. D. Ivanovsky

It has been found that the presence of certain impurities in cyanide liquors causes the formation of screening layers on the surfaces of gold and silver, these films retarding solution of the metal.

Copper, zinc and iron form films, which mainly consist of the complex cyanide anions and simple cyanides of these metals. The adsorption increases with increase in the concentrations of copper, zinc and iron in the solution. E.g., when the concentration changes from 0.01 to 0.5% Cu the amount of copper adsorbed on the surface of gold rises from $1.7 \cdot 10^{-5}$ to $40 \cdot 10^{-5}$ mg/cm², which corresponds to 0.3-7 monolayers of CuCN. The equilibria in the adsorption of copper, zinc and iron is established when the metal has been in contact with the solution for 4-6 hours.

The rate of solution of gold is observed to fall when the concentrations of copper, zinc and iron exceed 0.05%. The fall is greater with copper and much less with iron and zinc.

The adsorption of copper and zinc is much reduced by increasing the concentration of cyanide ions in the solution. The rate of solution of gold then rises.

The gold in the cyanide liquor is adsorbed by a metallic gold surface as $Au(CN)_2^-$ anions, the simple cyanide AuCN, and as gold atoms which enter the crystal lattice of the metal. The adsorption of gold on a silver surface is greater than on a gold one. Gold is reduced to the metallic form on a copper surface (cementation process).

Gold is more inert than silver and mercury in cyanide solution, and they displace it. When the silver concentration is up to 25 mg/liter, and the mercury up to 100 mg/liter, the solution of the gold becomes more rapid, due to the reduction of the more positive component. When the silver and mercury concentrations are higher, the rate of solution of gold falls.

At concentrations of 0.01-0.1, the sulfide ion is adsorbed on gold, forming alloy containing 8-17 monolayers. Under analogous conditions a solution of 80% Au + 20% Ag adsorbs 12-140 monolayers. The sulfur in the surface layer is present as the ions S^{-2} , HS^{-} and the compounds Au_2S and Ag_2S . The formation of shielding layers of sulfide enhances the retardation in the rate of solution.

Kalinin Institute of Nonferrous Metals and Gold,
Moscow.

STUDY OF THE BEHAVIOR OF ANTIMONY ON PURIFYING TELLURIUM BY THE VACUUM DISTILLATION METHOD

M. P. Smirnov and G. A. Bibenina

The investigations, which were carried out with the radioactive isotope Sb^{124} , on the behavior of antimony on purifying tellurium by vacuum distillation, showed that in the temperature range covered (450-600°) the degree of antimony transfer was 35-60%.

With the same fraction of the tellurium distilled over, the amount of antimony transferred to the distillate fell on raising the temperature and reducing the time taken to carry out the process.

Analysis of the condensate by zones showed that the zones closest to the evaporator gave the purest tellurium. Up to 90% of the tellurium was deposited in these zones.

Nonferrous Metals Research Institute.

STUDY OF THE BEHAVIOR OF ANTIMONY ON PURIFYING LEAD FROM BISMUTH

M. P. Smirnov and G. S. Rozhavsky

The radioactive isotope Sb^{124} was used to study the behavior of antimony in the process of removing traces of lead from bismuth.

The experiments showed that of the antimony inserted in the lead, some 95-99.7% passed over into the antimony-bismuth dross. It is possible that the formation of a quaternary intermetallic compound of approxi-

mate composition $Sb_{20}Pb_{80}$, Mg_{10} , in this process provides a more complete removal of the bismuth from the lead. Antimony originally present in the lead to the extent of 0.0005-0.007% differs in behavior from antimony added freshly. The original antimony takes no part in the process, and remains unchanged in the oven.

Nonferrous Metals Research Institute.

DISTRIBUTION OF COBALT BETWEEN MATTE AND SLAG

V. L. Khelifets and S. E. Vaisburd

This paper deals with the distribution of cobalt between the sulfide and silicate phases at low cobalt contents, down to $10^{-4}\%$ by weight, in synthetic and industrial conditions.

Melts of iron sulfide with slags containing cobalt, from water-jacketed furnaces, and from electric furnaces, as well as with fayalite, were made; also melts of water-jacketed and electric-furnace matte with these slags, and melts of iron sulfide mixed with nickel and copper sulfides with water-jacket slag.

The experiments showed that when the iron content of the slag was reduced, while keeping the basicity constant, the cobalt distribution coefficient (Co)_{slag/(Co)}_{matte} was reduced, particularly so when the basicity was also reduced (the fall being from 0.33 for fayalite, to ~0.001 for electric-furnace slag on remelting with iron sulfide). Increase in the metal content of the matte caused a marked fall in the cobalt distribution coefficient (by a factor of about 30 when the electric furnace matte contained 15% metal, as compared with a normal melt against a cobalt slag). The introduction of nickel sulfide, and more particularly copper sulfide, into the matte, raised the cobalt distribution coefficient, i. e., led to increased chemical losses with the slags when the slag composition was constant.

The data obtained confirmed the results of earlier studies on the reduction of losses of available materials in the slags when the cobalt content of the slag was small, as is typical of production systems.

It should be noted that over the temperature range used (1225-1275°), no effect on the cobalt distribution coefficient due to temperature was observed.

Gipronickel Research and Development Institute.

STUDY OF THE CONDITIONS UNDER WHICH ELEMENTS ACCOMPANYING COPPER PASS INTO THE GAS PHASE IN METALLURGICAL PRODUCTION

E. A. Vetrenko, N. P. Diev and A. I. Olesova

The conditions under which zinc and selenium evaporate off were studied. The completeness and rate of passage of the elements into the gas phase was determined by radioactive isotope methods. The methods used to prepare the tracer substances, which contained Zn^{65} and Se^{75} , are described, as well as the experiments on the sublimation and reduction of zinc sulfide, sublimed on heating above 850-900° in a neutral atmosphere. At 1250-1300° and atmospheric pressure, the evaporation was complete in 1.5-2 hours. Reducing the pressure

to 1-2 mm Hg, more than doubled the rate of sublimation. The zinc sulfide sublimed more rapidly on oxidizing the vapor, and fell on oxidizing the surface of the solid sulfide. This was most clearly shown when the zinc sulfide reacted with carbon dioxide. The sulfide vapor was reduced to the metal, the best reducing agent being copper metal.

The results from the experiments showed that, in spite of the low equilibrium, vapor pressure over the solid zinc sulfide sublimation of the sulfide plays an important part in the metallurgical process, and may lead to evaporation of the zinc at a high rate.

The experiments showed that the passage of selenium into the gas phase occurred via oxidation of the selenides. The rate of evaporation increased with temperature, but at 800°C and higher it began to fall, due to sintering of the selenides. In concentrate mixtures this caking did not occur at 800°C. When silver selenide was oxidized, the primary reaction products appeared to be selenium dioxide and silver metal. Later an intermediate phase between the metal film and the selenide arose: the composition of this has as yet not been elucidated.

Institute of Metallurgy,
Urals Branch of Academy of Sciences, USSR.

DIFFUSION AND THERMODYNAMIC CHARACTERISTICS OF SOME DILUTE SOLID SOLUTIONS

M. E. Yanitskaya and A. A. Zhukovitsky

It is important to determine the limitations of diffusion theory which relate the causes of the changes in the diffusion characteristics of solutions, due to the action of impurities, to the changes in the thermodynamic properties. To this end, the thermodynamic characteristics of solutions having both positive and negative deviations from Raoult's law (Ag-Cu and Ag-Sn respectively) were studied. The content of the second component in the alloys varied over the range from 0.1 to 5.0%.

The thermodynamic characteristics were determined by a method based on isotope exchange put forward by the authors.

The method was used to determine the values of thermodynamic activities.

The thin-film method was used to determine diffusion characteristics.

The measurements showed that the effect of the second component on the activation energy for self-diffusion of the solvent exceeded its effect on the heat of sublimation by a large factor, which may be explained by a fall in the potential barrier height while the base level remains practically unchanged.

A theory of the effect of impurities on the self-diffusion of the solvent was developed, this being based on the consideration of the mobility in a medium which contains sites of raised mobility which are distributed statistically.

The formula obtained is confirmed satisfactorily by the experimental data.

Stalin Steel Institute.

AN ADSORPTION METHOD OF STUDYING THE DIFFUSION AT EDGES AND IN THE BODIES OF METAL GRAINS

V. T. Borisov, V. M. Golikov, B. Ya. Lyubov and G. B. Sherbedinsky

This paper deals with the further development of an absorption method for determining diffusion parameters at the boundaries of, and within, grains of metals.

The experimental setup was adapted for continuous recording of the radioactivity in the specimen during diffusive annealing. A unit for recording the count rate automatically was developed.

A method of determining the layer thickness was developed, using the laws of β - and γ -ray absorption in the preparation.

The results presented were obtained by this method in the iron-silicon system (3% Si). It was shown that the activation energy and diffusion coefficient for iron at the grain-boundaries and within the grains did not depend on the grain size.

Central Ferrous Metallurgy Research Institute.

STUDY OF THE DIFFUSION OF CARBON IN STEEL ALLOYS USING THE RADIOACTIVE ISOTOPE C^{14}

P. L. Gruzin, Yu. A. Polikarpov, G. B. Fedorov and M. A. Shumilov

A method of determining the diffusion parameters for carbon, which was based on the use of the radioactive isotope C^{14} , was developed. The diffusion coefficient was determined from data on the total activity of the specimen obtained by cutting it into layers. It was shown that in this case the total activity of the residue was proportional to the carbon concentration within the layer taken. Using this fact, a simple formula for calculating the diffusion coefficients was derived. The method could also be of use with other β -emitters.

The diffusion of carbon in ferrite alloyed with nickel, cobalt, manganese and silicon was studied in this work. The compositions of the alloys used corresponded to the solid solution regions. It was shown that the introduction of chromium and molybdenum into α -iron leads to a certain change in the diffusion parameters for carbon (the activation energy rising from 26 to 33 kcal/g-atom). Alloying of α -iron with nickel and silicon influenced the diffusion of carbon slightly as compared with the elements which form carbides—chromium and molybdenum.

The effect of alloying nickel with chromium, cobalt and molybdenum was also studied. It was found that in this case the alloying affects the diffusion constants for carbon only slightly. Hence, it was concluded that the diffusion mobility of carbon in iron and nickel is not materially altered on alloying these elements.

The data showed that the rates of diffusion of carbon in ferrite and austenite were very different. This enables one to explain certain features of the stepwise cementation of steel.

Moscow Physico-Engineering Institute.

STUDY OF THE DIFFUSION OF COBALT IN MULTICOMPONENT ALLOYS OF FERRITE AND FERRITE/AUSTENITE TYPE

S. D. Gertsrinken, I. Ya. Dekhtyar, L. M. Kumok and E. G. Madatova

There are few data on diffusion in single-phase multicomponent alloys, and there are absolutely no data in the literature on diffusion in multicomponent alloys consisting of a mixture of two phases. The present work is concerned with this topic.

Eleven alloys based on iron were studied, the alloying elements being chromium, nickel, molybdenum, aluminum, zirconium and niobium. Of these, five were two-phase alloys ($\alpha + \gamma$), and six were single-phase ones (α -phase). The laws of diffusion in the alloys were studied by tracer methods. In order to determine the diffusion coefficient, the two-phase alloys were annealed at 900–1200°, while the single-phase ones were annealed at 800–1000°, by steps of 50°C. The annealing was carried out in an argon atmosphere to avoid oxidation of the alloys.

The graphs of $\log D$ vs. $1/T$ were straight lines for both two-phase and single-phase alloys, although the diffusion parameters for the separate phases were appreciably different.

The question of the relation between the effective diffusion coefficient in the alloy, D , and the diffusion coefficients in the separate phases, D_α and D_β , was considered, as well as the relation between the effective activation energy for diffusion, E , and the activation energy for diffusion in each phase. The values of D for the temperature range 1200–1500° were computed for the following phase ratios:

$$C_\alpha / C_\beta = 4/1; 2/1; 1; 1/2; 1/4,$$

and for the three cases:

$$E_\alpha > E_\beta, E_\alpha = E_\beta, E_\alpha < E_\beta.$$

Graphs of $\log D$ vs. $1/T$ were drawn up. In all cases, a linear relationship was obtained. Consequently,

$$D = D_0 e^{-E/RT},$$

and since it has been found that

$$E = C_\alpha E_\alpha + C_\beta E_\beta, \\ D = D_\alpha^{C_\alpha} D_\beta^{C_\beta}.$$

Then

These formulas were checked for the self-diffusion of zinc in a single crystal, since we have found no literature data on diffusion mixtures of two phases:

$$E = \frac{1}{3} E_{||} + \frac{2}{3} E_{\perp} = \frac{1}{3} \cdot 19600 \text{ cal/g-atom} + \\ + \frac{2}{3} \cdot 25900 \text{ cal/g-atom} = 23800 \text{ cal/g-atom}.$$

The experimental value of E for self-diffusion in a zinc polycrystal, which can be considered as a mixture of two phases, (perpendicular and parallel to the C axis), is also 23800 cal/g-atom. By analogy:

$$D_0 = D_0^{2/3} D_0^{1/3} = 0.38 \text{ cm}^2/\text{sec}.$$

The experimental value is $D_0 = 0.42 \text{ cm}^2/\text{sec}$. Thus, under defined conditions, in spite of the difference in the diffusion parameters in the separate phases, the effective diffusion coefficient in a two-phase mixture is covered by the normal formula:

$$D = D_0 e^{-E/RT}.$$

Tables 1 and 2 give values for the diffusion parameters in the alloys studied.

TABLE 1

Alloy	1	2	3	4	5	6	7	8	9	10	11
E , Kcal/g-atom	68	78	71	74.5	76.5	66.4	59.8	65.5	61.5	57.1	65.5

TABLE 2

No. of alloy	1	2	3	4	5
D_0 , cm^2/day	$3.16 \cdot 10^4$	$5.0 \cdot 10^4$	$0.6 \cdot 10^4$	$1.42 \cdot 10^4$	$1.78 \cdot 10^4$

No. of alloy	6	7	8	9	10	11
D_0 , cm^2/day	$1.00 \cdot 10^4$	$8.9 \cdot 10^4$	$4.57 \cdot 10^4$	$1.76 \cdot 10^4$	$1.7 \cdot 10^4$	$7.98 \cdot 10^4$

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DIFFUSION IN HETEROGENEOUS SYSTEMS

A. D. Sotskov, A. G. Rabinkin and A. A. Zhukhovitsky

This paper deals with the special features of diffusion in heterogeneous systems. The work was carried out by thin film methods in the Ag-Cu system. Silver was used as the diffusing element, this containing the radioactive isotope Ag^{110} . If the main specimen does not contain Ag^{110} , the coefficient obtained is a complex quantity, which describes both the diffusion and the self-diffusion. When the radioactive isotope is introduced in the base specimen at the same degree of enrichment as in the attached layer, only the diffusion coefficient is measured.

It was found that in the two-phase $\alpha + \beta$ region, the diffusion coefficient was zero, the self-diffusion coefficients over the whole of this region being the same. Diffusion and self-diffusion in the β region occur very rapidly, and the concentrations then become equalized in a few minutes. This is due to the formation of liquid micro-regions, which accelerate the diffusion considerably.

When the diffusion in the β region was studied, a very thin layer of silver (0.01 μ), was attached in one case, while in another case, the layer was about 1-2 μ . In the first case, the diffusion practically developed instantaneously in a homogeneous area, while in the second case, the experiment involved both the heterogeneous subsequent homogeneous stages. It is of importance that the transition from the first stage to the second does not occur continuously, but step-wise. Kinks were observed on the kinetic curves in the thin-film method. The later parts of these stepped lines coincided with the kinetic curves for the first case, while their slopes at short times after the start were clearly different. At temperatures above the eutectic point, the slope after short intervals was greater, and below this point, they were less, than at after long intervals. At temperatures above the eutectic point, this first stage in the process gives rise to a liquid layer which accelerates the diffusion, while below this line the diffusion in the first heterogeneous stage was complicated by phase changes, which retard diffusion. The rate of this stage, may, generally speaking, be defined by the rate of diffusion and by the kinetics of the phase formation process.

A treatment of the data indicates that the kinetic factor affects the initial phase of the experiment.

A consideration of the mechanism whereby the phase boundaries move, leads one to conclude that diffusion in a heterogeneous system takes a specific course, the effect being of Kirkendall type. It was shown that molybdenum wires, placed near the phase boundaries, were displaced when the boundaries moved.

It was also shown that neglect of the phase transformations gives an anomalously high effective activation energy.

Stalin Steel Institute.

DIFFUSION IN RESTRICTED SOLID SOLUTIONS BASED ON NICKEL

A. Ya. Shinyayev

The diffusion of iron in the restricted solid solutions formed in the nickel-titanium and nickel-chromium-tungsten-aluminum-titanium systems was studied as a function of the titanium content.

This choice for the diffusing element is due to the absence of a convenient radioactive isotope of nickel or titanium. Thus iron was taken for the diffusing element as it is the element most closely allied to nickel, on which the alloys are based.

The value of the diffusion coefficient was determined by a method we developed, which uses electrolytic polishing for removing layers, and by measuring the intensity of the radiation from the solutions obtained by electrolytic polishing of each layer.

The alloys studied fell in the unsaturated, saturated and two-phase regions of these systems. This enabled us to explain the effect of saturation of the solid solution in nickel on its diffusion characteristics. The diffusion coefficients were measured over a wide temperature range; thus, it was possible to determine the diffusion parameters with high accuracy.

The study of the diffusion of iron in the alloys in these systems showed that the curves relating the alloy composition to the diffusion coefficients had features typical of restricted solid solutions. At low temperatures, the curves relating the alloy composition to the diffusion coefficients had sharp minima in the regions where the solid solutions were saturated. As the temperature was raised, the minima were displaced towards the saturated solid solution side.

This fact enables us to deduce that saturation of a solid solution with alloying additives materially affects the changes in the alloy diffusion characteristics, causing occurrence of a minimum coefficient of diffusion and a maximum activation energy on the curves relating the alloy composition to the diffusion coefficients.

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STUDY OF THE DIFFUSION OF Co^{60} IN NICKEL/MOLYBDENUM ALLOYS

S. D. Gertsriken, I. Ya. Dekhtyar and V. S. Mikhailenkov

Heat-resisting alloys based on nickel in which the main added element is molybdenum are used very widely. Typical alloys of this type are such as "Khastella," which contain up to 30% Mo.

Diffusion in binary nickel/molybdenum alloys was studied; the compositions of these are given in the Table: Co^{60} was used as the tracer by the absorption method. Although the diffusion parameters are not characteristics which determine the heat resistance completely; nevertheless, the mobility of the atoms determines the maintenance of a given structure in the alloy, and the activation energy for diffusion reflects the strength of the interatomic bonds. The diffusion coefficients for cobalt in the alloys studied were determined over the temperature range 1050-1250°C; over this range, all the alloys are uniform solid solutions.

The diffusion coefficients, D , which were obtained, fall satisfactorily on a straight-line graph relating $\log D$ and $1/T$, and from this, the activation energy for diffusion, E , may be computed, as well as the pre-exponential factor D_0 .

The values of E and D_0 found are given in the table.

Mo, at. %	q	$D_0, cm^2/sec.$	$E, Kcal/mole$
3.14	0.784	0.078	66.0
7.01	0.939	0.21	69.0
10.29	1.0	6.35	79.6
12.99	—	0.086	66.5
16.79	—	0.046	65.0
20.56	—	0.0044	58.5

The curve relating activation energy for diffusion to concentration, which has a sharp maximum at the alloy with 10.29 at. %, is in good agreement with theoretical ideas as to the atomic interactions in alloys based on transition-group elements, in which the interaction of the S and d-electrons, by completing the incomplete d-orbitals, increases the strengths of the interatomic bonds. The degree of filling in the incomplete d-orbitals may be specified by a "completion coefficient":

$$q = \frac{d_0 - d_s}{d_0},$$

where d_0 is the number of unpaired d-electrons per atom in the gaseous state, as computed from spectroscopic data; d_s is the number of unpaired d-electrons per atom in the solid state.

The values of q computed for the alloys used, which are given in the Table, show that the activation energy for diffusion increases in the same way as q , as far as the alloy with 10.29 at. %, for which $q=1$. Further increase in the molybdenum content of the alloy raises the electron concentration, and thus, the kinetic energy of the electron system, while the potential energy is unchanged; this must lead to a drop in the energy of the atomic interactions, and thus, to a drop in the activation energy for diffusion, which is related to it.

The diffusion data can be used to derive the temperature coefficient of the elastic modulus. The pre-exponential factor D_0 is given by the formula $D = \gamma a^2 \nu \exp \left(-\frac{E}{RT} \right)$, where $\beta = -\frac{1}{R} \cdot \frac{dD}{dT}$ is the temperature coefficient of the elastic modulus, found from the straight line graph relating $\log D_0$ and E/R .

The mean temperature coefficient of the elastic modulus estimated from the diffusion data obtained on the alloys used was $7.8 \cdot 10^{-4} \text{ } ^\circ\text{C}^{-1}$ over the temperature range studied.

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EFFECT OF MANIFOLD COMPRESSION ON THE SELF-DIFFUSION IN POLYCRYSTALLINE ZINC

S. D. Gertsriken and M. P. Pryanishnikov

The self-diffusion parameters of polycrystalline zinc were determined by tracer methods in this work at hydrostatic pressure of 1-3 atm. and 80 atm., over the temperature range 270-380°. The work was carried out on All-Union State Standard 989-41 zinc, in the forms of cubes and strips.

The experimental data are given in the table below.

The following expressions were obtained for the temperature dependence:
at pressures of 1-3 atm.

$$D = 3.71 \cdot 10^8 \exp \left(-\frac{26400}{RT} \right) \text{ cm}^2/\text{day},$$

at a pressure of 80 atm.

$$D = 9.73 \cdot 10^4 \exp \left(-\frac{22000}{RT} \right) \text{ cm}^2/\text{day}.$$

t, °C	P = 1-3 atm		P = 80 atm	
	D · 10 ⁸ , cm ² /day		D · 10 ⁸ , cm ² /day	
	strip	cube	strip	cube
270	0.97	0.66	1.47	0.93
290	1.75	—	3.22	2.69
300	2.20	—	5.05	4.63
307	—	—	6.10	4.95
312	3.73	2.71	9.27	8.33
336	11.2	—	17.8	12.2
356	—	—	22.9	16.8
375	50.4	—	71.9	52.8
380	47.7	42.4	34.8	24.1

Consequently, close compression of the specimens reduces the activation energy of self-diffusion considerably, and raises the atomic mobility appreciably.

For example, the activation energy drops from 26.4 kcal/g-atom at 1-3 atm. to 22 kcal/g-atom at a pressure of 80 atm. The self-diffusion coefficient increases by a factor of 1.5-2.5.

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STUDY OF THE DIFFUSION IN ZIRCONIUM AND SOME OF ITS ALLOYS BASED ON RADIOACTIVE ISOTOPE METHODS

E. V. Borisov, Yu. G. Godin, P. L. Gruzin, A. I. Evstyukhin and V. S. Emelyanov

This paper deals with the study of self-diffusion in zirconium, zirconium/tantalum and zirconium/nibium alloys containing 2.5% Ta and 10% Nb, in a ternary zirconium alloy containing 1.33% Nb and 0.67% Ta, and the diffusion of tantalum in zirconium.

The study of self-diffusion and the diffusion of tantalum in zirconium was carried out on specimens of zirconium prepared by the iodine method. The alloys used for the diffusion work were made in an arc furnace, type MFI-SM-3.

The diffusion coefficients were determined by measuring the total activity of the specimens. The isotope Zr^{90} was used in the experiments on self-diffusion in the form of a metallic powder, while in the experiments on the diffusion of tantalum in zirconium, radioactive tantalum metal, containing Ta^{182} was used.

The self-diffusion and diffusion coefficients were determined in the α and β regions for pure zirconium. In the alloys the self-diffusion coefficients were determined in the β region in the two-phase $\alpha + \gamma$ region.

The temperature variations of the self-diffusion coefficients for zirconium were defined by the equations:

$$D_{\beta-Zr} = 10^{-4} \exp \left(-\frac{27000}{RT} \right) \text{ cm}^2/\text{sec}$$

$$D_{\alpha-Zr} = 10^{-7} \exp \left(-\frac{22000}{RT} \right) \text{ cm}^2/\text{sec}$$

In the case of the diffusion of tantalum in zirconium the temperature variation of the diffusion coefficient took the form:

$$D_{\beta-Zr} = 5 \cdot 10^{-6} \exp(-27000/RT) \text{ cm}^2/\text{sec}$$

$$D_{\alpha-Zr} = 10 \exp(-70000/RT) \text{ cm}^2/\text{sec}.$$

The results on the diffusion parameters in the β region alloys show that alloying zirconium with tantalum and niobium raises the activation energy and retards the diffusion somewhat.

The diffusion coefficients for alloys falling in the two-phase region were determined approximately, since their values were found to be at the limits of sensitivity of the method used.

Comparison of the self-diffusion coefficients for zirconium, cobalt, nickel, iron and chromium, which all have about the same melting point, shows that zirconium differs from the other metals in having a high diffusion mobility, and low activation-energy values. These results enable one to elucidate some of the special features shown by the behavior of zirconium alloys at high temperatures. In particular, one may suppose that the comparatively low limiting temperature of heat resistance in zirconium alloys is due to the high rate of the diffusion processes.

It may be supposed that the main cause of the high diffusion mobility in zirconium alloys is an intragranular structural factor. Its importance in this case is due to the $\beta \rightarrow \alpha$ phase transformation.

Moscow Physico-Engineering Institute.

STUDY OF THE DIFFUSION; SOLUBILITY AND SEGREGATION OF SOME IMPURITIES IN GERMANIUM BY RADIOACTIVE ISOTOPE METHOD

A. A. Bugai, V. N. Vasilevskaya, V. E. Kosenko and E. G. Miselyuk

The following investigations were carried out in this work:

- the diffusion and solubility of silver and iron in germanium over the temperature range 700-930°;
- the segregation and solubility of silver, iron, tin, and antimony in germanium on crystallization.

Methods. The studies of the diffusion and solubility of silver, as well as those on the segregation and solubility in germanium on crystallization, were carried out by tracer methods, using the radioactive isotopes Ag^{110} , Fe^{59} , Sn^{114} , Sb^{124} .

The experiments on the solubility and diffusion coefficient were made on specimens of pure germanium monocrystal, with specific resistances greater than 85 ohm-cm. Diffusive annealing of the specimens with iron was carried out in vacuo, while the diffusive annealing of the specimens with silver was carried out in an argon atmosphere.

The segregation of impurities upon crystallization was studied by measuring the ratio

$$K = \frac{C_S}{C_L},$$

where C_S is the impurity concentration in the crystal;
 C_L is the impurity concentration in the liquid.

This ratio defines the effective segregation coefficient under the given conditions of crystallization.

The impurity concentrations in the germanium were determined from the activity of the specimen, while the solubility at the temperature of crystallization was computed from the value C_S , at which the value of K began to increase sharply.

The activity measurements were made using a γ -ray scintillation counter.

Results and Discussion. The limiting solubilities C_0 for silver and iron in germanium have maximum values: for silver at 875° $C_0 = 1 \cdot 10^{15} \text{ cm}^{-3}$, while for iron at 850° $C_0 = 1.5 \cdot 10^{15} \text{ cm}^{-3}$. At 750° the solubility for silver falls to $C_0 = 1 \cdot 10^{14} \text{ cm}^{-3}$, and for iron to $C_0 = 6 \cdot 10^{14} \text{ cm}^{-3}$. The diffusion coefficients in germanium were expressed by the formulas:

$$\text{for silver } D = 4.4 \cdot 10^{-6} \exp(-22000/RT)$$

$$\text{for iron } D = 0.136 \exp(-24000/RT),$$

where R is the gas constant and T is the absolute temperature.

The anomalously high diffusion coefficients for silver and iron in germanium, as well as the comparatively low activation energy for diffusion, enable one to assume that the mechanism of diffusion for these elements is interstitial.

From the values of C_S and C_L the segregation coefficients were determined, the values obtained being: for iron $K_0 = 1.0 \cdot 10^{-5}$, tin $K_0 = 1.5 \cdot 10^{-5}$, antimony $K_0 = 2.5 \cdot 10^{-5}$ and silver $K_0 = 1.5 \cdot 10^{-6}$. The work showed that the effective segregation coefficients for these impurities begin to increase sharply at certain values of C_S , these being, for iron $C_S = 3.0 \cdot 10^{15} \text{ cm}^{-3}$, tin $C_S = 2.0 \cdot 10^{15} \text{ cm}^{-3}$, antimony, $C_S = 6.0 \cdot 10^{15} \text{ cm}^{-3}$, and silver $C_S = 1.5 \cdot 10^{15} \text{ cm}^{-3}$.

From metallographic data and from autoradiograms it was possible to explain the sharp rise in K_0 at the commencement of the elimination of the impurities at the grain boundaries in the mosaic and within the grains which were in excess of the limiting solubilities.

On the basis of these data, it is asserted that the values of C_0 given above correspond to the solubility limits for these impurities in germanium at the crystallization temperature.

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STUDY OF THE DIFFUSION OF SOME METAL IN SELENIUM

A. A. Kuliev

Here the diffusion of iron and zinc in selenium, which is widely used in selenium rectifiers and rectifier photocells, was studied.

The work was performed with radioactive tracers by Kryukov and Zhukovitsky's method, using β -ray absorption.

Selenium foils of thickness 110 μ were used, these being made from selenium of 99.996% purity, which had been homogenized and crystallized at 130°C and 200°C for several hours. Radioactive iron and zinc were deposited on one side of the foils by electrolysis.

The specimens were given diffusive annealing, and then the ratio of the radiation intensities on the two sides of the foil were measured as a function of the annealing time.

The annealing was carried out in vacuo at a temperature constant at 0-5°C. The experiments were performed at 40, 70 and 100°. The experimental data showed a relation between the diffusion coefficient and the atomic radii of the elements diffusing. The activation energies were computed from the experimental data. The dif-

fusion coefficients of germanium, mercury and sulfur in selenium were also determined.

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EFFECT OF ALLOYING ON THE STATE OF THE CARBON ATOMS IN ALLOYS

Yu. F. Babikova and P. L. Gruzin

1. The properties of metallic alloys depend on the nature of the interactions between the metal atoms in the alloy. Much attention has therefore been devoted to elucidating the states of atoms in solid solutions. Valuable information on the question has been obtained from the intensities of x-ray diffraction patterns. More direct information about the states of atoms in alloys can be obtained from atomic transfer in electric fields. The data so obtained on transfer, are also of some practical interest.

2. The method used for studying carbon transfer in solid solutions was as follows: a) preparation of specimens saturated with radioactive carbon C^{14} , by sintering; b) annealing of the specimens in an oven while simultaneously passing electric currents through them; c) activity measurements on the specimens; d) drawing up longitudinal radioactive distribution curves and computation of the transport number (n). The method developed makes it possible to study carbon transport in alloys quantitatively.

3. The report presents the main results for the transport of carbon in ferrite and nickel at temperatures in the 500-900°C range. Data were also obtained on the effect of adding small amounts of various elements to the ferrite and nickel. The temperature dependence of the transport numbers was determined for the following alloys: Fe-Ni (1%); Fe-Ni (2%); Fe-Cr (2.5%); Fe-Cr (6%); Fe-Mn (1%); Fe-Mn (2%); Fe-Si (2%); Fe-Si (3%); Ni; Ni-Cr (1%); Ni-Cr (4%).

Data of greater importance are those relating to the degree of ionization of the atoms in the lattice, i. e., the values of the ionic charges z , rather than the transport numbers. The relation between z and n may be expressed as follows:

$$z = \frac{8.95 \cdot 10^{-8} n T}{D \rho c}$$

where D is the diffusion coefficient; ρ is the specific resistance and c is the concentration difference in the specimen.

The charges on the carbon ions in the above alloys were computed from the formula. At the temperatures used, the charges on the carbon ions were roughly the same in all alloys.

4. It was found that in α -iron and nickel was transferred toward the cathode when an electric field was applied. The carbon cationic charges were about 4 units in ferrite and 2 in nickel. The addition of silicon and nickel reduced the degree of ionization in the carbon by about 2 units. Addition of chromium to the ferrite did not cause a noticeable change in the charges on the carbon ions in the ferrite, while on alloying nickel with chromium, the charge on the carbon cations increased by 3-4 units. The carbon atoms dissolved in a ferrite alloyed with manganese had charges of 3-4 units.

5. It was found that all the carbon atoms dissolved in these alloys were ionized.

Central Ferrous Metallurgical Research Institute.

STUDY OF THE DIFFUSION OF IRON IN REFRACTORIES USING THE ISOTOPE Fe^{59}

E. A. Prokofyeva and V. V. Goncharov

As metallurgical processes are intensified, the wearing out of basic refractories increases continually. This primarily refers to magnesite-chromite refractories used for lining the cupolas of steel-melting ovens. Refractories containing chromite have a definite tendency to take up iron oxides, and this is the most important factor contributing to their destruction in use. Hence, a study of the type and mode of diffusion of iron oxides in basic refractories, and above all, in cupola ones, is of great practical importance.

The diffusion coefficients, D , were determined by the usual method of taking layers, using the isotope Fe^{59} .

D was determined at 1500, 1600 and 1700° for magnesite, magnesite-chromite and chromite refractories; the following results were obtained: a) the value of D is directly related to the porosity, in general; b) the basic refractories can be arranged as follows, in order of increasing D :

Refractory	Temperature, °C.	Porosity %	$D \cdot 10^4$, cm^2/sec
Magnesite	1600	20.5	22.0
Magnesite-chromite	1600	22.7	34.0
Chromite	1600	18.2	42.0

c) the value of D increases more rapidly over the range 1500-1600° than it does over the range 1600-1700°.

The type of diffusion shown by iron oxides in Dinas bricks, differs sharply from those in the refractories above, and is the least stable to penetration by iron oxides, as compared with them.

The value of D and the diffusion length may be used for comparative quantitative calculation of the tendency of refractories to absorb iron oxides.

Refractories Institute.

STUDY OF THE DIFFUSION PROCESS OF IRON AND CHROMIUM IN THE OXIDES α - Al_2O_3 , σ - Cr_2O_3 , NiCr_2O_4 and NiAl_2O_4

D. V. Ignatov, I. N. Belokurova and M. N. Belyanin

The study of oxidation processes in alloys based on the systems Fe-Cr-Al and Ni-Cr-Al, which are widely used in practice with small amounts of other elements added is of great interest, particularly as regards the diffusion parameters of iron and chromium in the oxides which form on these alloys at high temperatures: i. e., σ - Al_2O_3 , α - Cr_2O_3 , NiCr_2O_4 and NiAl_2O_4 .

The specimens used were prepared by sintering the compressed oxides at 1200-1600°.

Layer sampling was used to determine the diffusion process. The layers of active iron or chromium, of thickness from 0.1 μ to 1 μ , were transferred to the specimens by evaporation in vacuo. The diffusive annealing was carried out in quartz tubes or ampules in vacuo of about 10^{-4} mm Hg at 900-1200° for chromium and 1000-1200° for iron. These temperature ranges were chosen so that the diffusion and oxidation parameters could be compared.

The results showed that in this temperature range, the diffusion coefficients for chromium and iron in these oxide systems varied exponentially with temperature.

The values of the activation energies and pre-exponential factors computed by the method of least squares, are given in the table.

System	Q, kcal/mole	D, cm ² /sec
Diffusion of Cr:		
α - Cr_2O_3	22000	$4.29 \cdot 10^{-8}$
NiCr_2O_4	44800	$2.03 \cdot 10^{-8}$
NiAl_2O_4	50000	$1.17 \cdot 10^{-8}$
Diffusion of Fe:		
α - Cr_2O_3	44000	$4.95 \cdot 10^{-8}$
NiCr_2O_4	61000	$1.35 \cdot 10^{-8}$
α - Al_2O_3	82000	1.13

The values of the activation energies obtained were in agreement with the rates of oxidation in the alloys based on Ni-Cr-Al, and with the rates of evaporation and the heats of formation of the oxides α - Cr_2O_3 , α - Al_2O_3 , NiCr_2O_4 , NiAl_2O_4 .

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MEASUREMENT OF THE VAPOR PRESSURE OF SOLID SUBSTANCES AND THEIR BINARY ALLOYS

A. N. Nesmeyanov

Radioactive isotopes were used to measure the vapor pressures by isotope exchange methods, and also in some of the various static methods—those due to Knudsen and Langmuir.

The vapor pressure of solid arsenic, bismuth, silver, zinc, cadmium, antimony, calcium, strontium, gold and copper were measured, as well as those of the binary alloys Zn-Cd, NaCl-KCl, KCl-RbCl, Sb-Ag, Sb-Cu, Ag-Cu.

The radioactive isotopes used were As^{74} , Zn^{65} , Cd^{115} , Sb^{124} , Ca^{45} , Sr^{90} , Au^{198} , Ag^{110} , Cu^{64} , Na^{24} and Rb^{86} .

The measurements showed that the vapor pressure of the components in the eutectic melts (Zn-Cd, NaCl-KCl) were equal to those of the pure components.

Melts which form chemical compounds can be divided into two types. The first type comprises those compounds which decompose at the surface on evaporation, the alloy behaving as a solid solution. The second type does not give compounds which decompose on evaporation, and measurement of the vapor pressures of the components separately gives the same results.

The data on the vapor pressure of the components in solid solutions show negative deviations from Raoult's law for alloys of gold with silver and copper, and complex shapes for the curves relating the vapor pressures of the components to the composition of the solid solutions formed between potassium and rubidium chlorides.

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USE OF ISOTOPES FOR STUDYING THE MOBILITY OF ATOMS AND INTERATOMIC INTERACTIONS IN METALS

E. Z. Vintalkin, P. L. Gruzin and S. N. Fedorov

Much attention has been given to atomic interactions in metals and alloys in recent years. The quantities which define the strengths of the interatomic bonds are the heat of sublimation and the vapor pressure. Radioactive isotopes are used to determine these parameters for metals. However, no convenient radioactive isotopes are available for some metals. In such cases, stable isotopes and mass spectrometry are used.

The report describes a method for determining the vapor pressures of metals based on line-intensity measurements in the mass spectrometer. This method has a number of advantages. In particular, it is possible to study the structure of particles in the gas phase and simultaneously, to measure the vapor pressures of several components of the alloy. The report describes the results obtained by the new method for the heats of sublimation of cadmium, zinc and silver.

Central Ferrous Metallurgy Research Institute

DETERMINATION OF THE THERMODYNAMIC CHARACTERISTICS OF THE COMPONENTS IN ALLOYS

A. P. Lyubimov and A. A. Granovskaya

Determination of the thermodynamic characteristics of the components in alloys in the solid and liquid states is of great importance for solving problems in theoretical metallurgy. The method most widely used for deriving these quantities is the evaporation method, the vapor phase being analysed subsequently, and the partial vapor pressures being determined. It is very convenient to use a mass spectrometer for the analysis, the composition of the vapor phase being thereby, determined directly: very small amounts of the substances are also sufficient for this purpose. The latter circumstance is extremely important in studying solid alloys at high temperatures, since the surface of the specimens may become appreciably depleted of readily evaporating component.

The method was checked on the binary systems Fe-Ni and Fe-Co at temperatures in the range 1150-1430°. The concentrations of the components in the vapor phase were determined, using the isotopes Fe⁵⁴, Ni⁵⁸, Ni⁶⁰ and Co⁵⁹. During the experiment the ion currents were measured, the ratios of these corresponding to the ratios of the concentrations of the components in the vapor phase at each temperature and concentration.

To determine the partial vapor pressures, the following expression, derived from the Gibbs-Duhem equation, was used:

$$\ln \frac{P_a}{P_b} = - \int_{N_a=1}^{N_a} \frac{N_a}{N_a} dN_a - \int_{N_b=0}^{N_b=1-N_a} \frac{N_b}{N_b} dN_b, \quad (1)$$

where P_a is the total pressure due to both components;

P_a is the vapor pressure of the pure component a at the temperature of the experiment;

N_a and N_b are the molar fractions of the components in the solid phase;

N_a and N_b are the molar fractions of the components in the vapor phase.

The numerical values of the integrals appearing in formula (1) were found from the graphs of the relationships

$$\frac{N_a}{N_a} = f(N_a)$$

and

$$\frac{N_b}{N_b} = \varphi(N_b).$$

The results obtained showed that the Fe-Ni and Fe-Co systems were close to ideal in this temperature range, and only at the lowest temperatures used were there small deviations from ideality.

Stalin Steel Institute, Moscow.

STUDY OF THE DISTRIBUTION OF CARBON IN IRON ALLOYS BY RADIOGRAPHIC METHODS

A. S. Zavyalov and B. I. Bruk

The problem of the redistribution of carbon in iron alloys upon heat-treatment has not received a satisfactory experimental solution so far.

The present work deals with the study of the redistribution of carbon in iron alloys, in which the alloying elements are, separately, nickel, chromium, silicon, manganese and molybdenum, and which contain 0.03-0.05%C the work being carried out by autoradiography, using the carbon isotope C¹⁴.

The studies of the radioactive alloys by autoradiography in the annealed state made it possible to show that all these alloys, after being annealed, showed a nonuniform distribution of carbon, the grain boundaries being enriched.

It was found that by quenching from temperatures of 950 and 1200°, all the autoradiographs gave a uniform blackening, which shows that the distribution of carbon is uniformly relative to the grain boundaries in austenite.

When the alloys of iron with chromium and manganese had stood at 590°C for 10 hours, the carbon distribution in them appeared as uniform as before, while in the alloys with nickel, silicon and molybdenum there was a marked redistribution of the carbon towards the intergrain boundaries. This confirms the hypothesis that chromium and manganese freeze in the structure, being elements which form carbides, preventing the redistribution of the carbon on annealing; and that the elements which do not form carbides (Si and Ni) intensify the processes which eliminate carbon.

As regards the Fe-Mo alloys, the rapid diffusion of carbon to the grain boundaries on tempering this alloy, is explained by the fact that at a molybdenum content of 12.5%, the alloy becomes two-phase, the former being disposed around the grain boundaries, as occurred in the previous work.

The uniform distribution of carbon with regard to the grain boundaries which was found in the Fe-Cr and Fe-Mn alloys as a result of tempering, confirms that the alloying elements themselves (Cr and Mn) do not concentrate near the austenite grains, or else the carbon would diffuse to the grain boundaries when these alloys are tempered.

Ministry of Shipbuilding Industry.

NATURE OF THE INTERGRANULAR FRACTURE OF CAST AND REHEATED STEELS

M. A. Studnits and I. L. Mirkin

The majority of investigators attribute the origin of the structures which lead to intergrain fracture in steel to the enrichment of the austenite grain boundaries with various elements. The mechanism of enrichment has been dealt with in different ways in the various papers.

Using autoradiography, the distributions of C, S, Si, W, Mo, Ni, P and Cr in steel were studied, these showing intergrain fracture. It was found that S, Mo, P, Cr and C accumulate at austenite grain boundaries; W, Si and Ni do not.

This work showed that the formation of structures in steel which lead to intergrain fracture occur owing to maintenance of steel above some critical temperature for a long time, this temperature being termed the granulation temperature (T_{gr}). Study of the redistribution shown by the elements when the granulation structures form, demonstrated that above T_{gr} , the mobilities of elements which accumulate at grain boundaries rose by a factor of more than 10^4 .

The mobilities of elements which do not accumulate at grain boundaries changed slowly with temperature. It was deduced that intergrain fracture is due to the appearance at austenite grain boundaries of liquid sub-layers. These sub-layers result from the fusion of the eutectic present in the steel. The conditions leading to intergrain fracture in steel may be completely eliminated by removing the low-melting eutectic from the steel by treating it with elements which form high-melting compounds with sulfur, such as cerium.

Branch of the All-Union Research Institute,
Ministry of Transport Machine Construction.

CALCULATION OF THE AMOUNTS OF β -RADIATION REQUIRED FOR RADIOGRAPHIC AND RADIOMETRIC STUDIES

L. M. Efimov

There are, at present, almost no data with which to compute the minimum concentration of active additive required in the specimen under study, which will ensure an autoradiograph of the requisite density within a given time period. So far, not even the simpler connection between the specific activity of the tracer in any medium and the flow of β -particles and secondary electrons ejected from unit surface has yet been derived.

The present paper constitutes an attempt to perform a theoretical calculation of the electron flux from the specimen, and on this basis to decide how much β -emitting tracer is required for activity measurements and radiography.

Central Ferrous Metallurgy Research Institute.

RADIOGRAPHIC STUDY OF THE NONUNIFORMITY OF INTRA- CRYSTALLITE SULFUR AND PHOSPHORUS IN WELDED JOINTS

B. A. Movchan and L. A. Poznyak

The radioactive isotopes of sulfur and phosphorus have been widely used in studying intracrystallite non-uniformities in welded joints. Butt-welded joints constitute a special part of the metal sheet which is usually not given any subsequent heat treatment. The intracrystallite nonuniformities formed in the primary crystallization period affect the physico-mechanical properties of the welded joint in an important fashion. Some work has been carried out at the Institute of Electric Welding, which was concerned with the macroscopic and microscopic chemical nonuniformities in welded joints, the radioactive isotopes of sulfur (S^{32}) and phosphorus (P^{32}) being used. The following results were obtained from this work.

1. In welded joints produced under average welding conditions, the intracrystallite nonuniformities, as judged from the sulfur and phosphorus, were 100% less than in billets of the same chemical composition which were cooled slowly.

2. Increasing the rate at which the metal in the welded joint was cooled reduced the intracrystallite non-uniformities of sulfur and phosphorus. Preheating of the welded metal increased the intracrystallite nonuniformity in the welded joint.

3. The boundary zones in the crystallites, which were enriched in sulfur, were of considerable width in welded joints made from low-carbon steels, constituting a supersaturated solid solution. Sulfides were absent from these zones.

4. In welded joints made from stainless steel type 1Kh18N9, raising the nickel contents somewhat increased the intracrystallite nonuniformities due to sulfur.

5. Increasing the carbon content in the welded joint metal raised the intracrystallite liquation of sulfur considerably: when the carbon content in the welded joint metal was greater than 0.2%, sulfides appeared, these being demonstrated by the usual methods.

6. Increasing the manganese contents of welded joints in medium carbon steel caused a drop in the intracrystallite liquation of sulfur.

Paton Institute of Electric Welding,
Academy of Sciences, Ukrainian SSR.

STUDY OF THE REDISTRIBUTION OF CHROMIUM IN THE ARC WELDING OF STAINLESS STEEL BY RADIOACTIVE INDICATOR METHODS

B. I. Bruk

When chrome-nickel stainless steels are welded, it is essential to ensure that their tendencies to hot fracture are avoided, as well as to maintain the desired anti-corrosion and mechanical properties of welded joints. This implies that a definite minimum amount of chromium must be retained in the metal joint for a given nickel content.

In order to replace the lack of chromium in the joint metal, which is due to its being burnt up in the welding, definite quantities of chromium have to be included in the electrode coating. The experimental determination of the amounts required is of considerable difficulty, since the sources from which the chromium in the joint is derived are the base metal, the rod and its coating; the degrees to which the chromium from these sources enters the joint are not the same.

In order to determine the utilization factors for the chromium in the base metal, the rod and its coating, separately, radioactive isotope methods were used, the tracer isotope being Cr^{51} . The isotope was included separately in the base metal, the rod and its coating, which made it possible to determine the utilization factors for the chromium from all three sources separately, although large amounts of chromium were present at the same time in all of them.

The work was carried out with stainless steel type 1Kh18N9T and with Tsl-11Kh electrodes.

The activities of metal and slag were assayed using a cylindrical aluminum-wall counter. From the activity measurements of the part due to each ingredient in the weld, chromium was determined.

Using this method, it was determined that the burn-up of chromium appearing in the joint metal from the base and feed metals was some 13% of the initial content. This lack of chromium in the joint can be replaced by introducing 8-9% of metallic chromium into the electrode coating.

Special experiments showed that in order to provide the required minimum chromium content in the joint at various nickel concentrations (from 8-11%) the chromium concentration in the coating had to range from 6 to 21%. This shows that it is desirable to label Td-11Kh electrodes differently according to the content of chromium metal in the coating.

Ministry of the Shipbuilding Industry of USSR.

QUANTITATIVE CALCULATION OF DENDRITIC LIQUATION IN STEEL AUTORADIOGRAPHY WITHOUT USING STANDARDS

M. F. Longinov

Autoradiography gives a direct picture of the distribution of elements in alloys; it is fairly simple and is widely used at the present time for studying processes which affect the uniformity of alloys.

One shortcoming in the method is the need to prepare standards in which the element used must be evenly distributed throughout the whole mass. This restricts the use of autoradiography, since some elements are practically impossible to distribute uniformly in steel.

The method proposed does not require preparation of standards and so may be applied in studying the uniformity of any alloy.

In order to determine the exposure needed to give normal blackening of the emulsion (linear range on sensitivity curve), autoradiograms are taken with the same specimen at different exposures. The regions of greatest and least density were then photometered. Two independent blackening curves were then drawn up from the photometric results.

When the normal exposure had been determined, the autoradiograms, with their normal exposures corresponding to the parts of greatest and least density, were photometered, after which curves for the distribution of blackening were drawn up.

Since the blackening curves are also curves of element concentration, the area bounded by the density curve is numerically equal to the amount of activity in the area photometered. The ratio between the numerical value for this area, and the length of the section gives the mean concentration of the element on some (still unknown) scale.

In order to determine the concentration values relating to the various parts of the autoradiogram, the concentration scale had to be calibrated; since the concentration scale is linear, any other method (e. g., chemical) of determining the mean concentration of the element is adequate.

This method was used to determine the dendritic liquation of sulfur and tungsten in rolled steel, and also after annealing to homogeneity.

Zlatoust Metallurgical Works.

EFFECT OF MODIFYING ADDITIVES ON THE DISTRIBUTION OF SULFUR IN HIGH-CHROMIUM HEAT-RESISTING STEEL

N. S. Kreshchanovsky and S. V. Kraskovsky

The output, longevity and operational characteristics of current prime movers depend in many ways on the properties of the heat-resisting steels and alloys used. The quality of these latter is determined by the presence and distribution of harmful impurities (S, P, As, etc.) as well as by their compositions, the impurities being inevitably present to some extent in the alloys. It is only possible to decide on ways of restricting their effects by micro-alloying (modification) after having studied the actions of the modifiers on the distribution of undesirable impurities in detail.

The report presents results on the effect of certain elements on the sulfur distribution in KhPV2M high-chromium heat-resisting steel. S^{35} was used. Lithium, calcium, cerium and other elements were used as modifiers. The macro- and microdistribution of sulfur were studied.

The effect of the additives on the macrostructure of the steel was considered, as well as the sulfur redistribution due to the modifiers. The objective value of sulfur-distribution data obtained by Baurmann's sulfur off-print method, was also made apparent.

This work enables one to evaluate the use of modifiers in casting high-chromium heat-resisting steel.

Central Technological and Machine Construction
Research Institute.

STUDY OF THE PROCESS OF MIXING AND DIFFUSION IN WELDED SEAMS OF TWO-LAYER JOINTS USING RADIOACTIVE ISOTOPES

E. M. Kuzmak and N. P. Karmazinov

This paper deals with transfer effects in the welding furnace and heat-treatment cycle, in relation to the weldability of two-layer rolled iron.

The radioactive isotopes S^{35} and C^{14} were used to study mixing and diffusion in welded joints made from MST3 - 08x12 two-layer rolled iron.

The degree of uniform mixing of the different steels during automatic welding was determined by using radioactive sulfur, as well as the macro- and micro-uniformity of the joint made from the different steels (i. e., of the joint metal in the clad layer).

The cause of the relative fall in the corrosion resistance of the 08 x12 layer in the region affected by the heat was elucidated by introducing radioactive carbon.

From the sulfur distribution radiographs for welded joints of the different steels made by automatic welding, the predominant role of mixing in producing a uniform chemical composition over the welded area became apparent: a criterion for automatic welding was thus set up which related the initial chemical composition of the chromium-nickel electrode and the final chemical composition of the joint metal.

The work showed that the relative fall in the corrosion resistance of the heated zone in the 08 x 12 layer was due to redistribution of the carbon. The back-diffusion of carbon from the carbonaceous zone via the welding line to the previously carbon-free zone was demonstrated.

The C^{14} and S^{35} radiographs also gave data on the metallurgical behavior of sulfur and carbon in welds made from different classes of steel.

Gubkin Oil Institute.

EFFECT OF FAST-NEUTRON IRRADIATION ON THE RECOMBINATION OF ELECTRONS AND HOLES IN GERMANIUM CRYSTALS

V. S. Vavilov, A. V. Spitsyn, L. S. Smirnov and M. V. Chukichev

Fast-neutron irradiation causes structural defects in crystals. The equilibrium carrier concentration, mobility and rate of electron-hole recombination in semiconductors are altered by destruction of the periodic crystal structure. The rate of recombination (lifetime) of nonequilibrium carriers is the property most sensitive to irradiation in pure crystalline semiconductors (germanium, silicon).

N-type germanium single crystals of specific resistance 30 ohm-cm were irradiated with neutrons, the neutron flux being 10^{11} n/sec 1 /cm 2 at the specimen location.

It was found that fast-neutron irradiation causes a drop in the nonequilibrium carrier lifetime in germanium (increase in the rate of volume recombination), while the specific resistance changed by about 1% when the lifetime had dropped by a factor of several times.

The recombination cross section, σ_n , was estimated for the lattice defects produced by the neutrons. The fast-neutron scattering cross section for germanium nuclei was used to compute the number of defects produced per neutron, as well as the formula for the number of atoms secondarily displaced. The value of σ_n was $(1.1 \pm 0.5) \cdot 10^{16}$ cm 2 , this being considerably greater than the recombination cross section, σ_e , for the lattice defect produced by fast-electron bombardment of germanium: $\sigma_e \approx 7 \cdot 10^{17}$ cm 2 . The cause of the large difference between σ_n and σ_e may be that neutron bombardment, unlike electron bombardment, causes defects which are efficient recombination centers, to accumulate.

Lebedev Institute of Physics, Academy of Sciences, USSR.

STUDY OF THE SUPERLATTICE IN Ni_3Fe BY NEUTRON DIFFRACTION

B. G. Lyashchenko, D. F. Litvin, I. M. Puzel and Yu. G. Abov

With the development of nuclear reactors, a real possibility of using neutron radiography in scientific research has appeared. The present paper, which is the first USSR study of this type, is concerned with the analysis of structural states in the solid solutions based on nickel and iron.

The atomic ordering effects found in the alloy of stoichiometric composition Ni_3Fe by direct x-ray study, and later by neutron diffraction, may give a qualitative explanation of the anomalous physical and technological properties observed in the permalloys on heat-treatment and alloying. The question of the stimuli which cause the atomic ordering within the lattice sites is still not solved, in our opinion, like some other important general questions. The main difficulty is the slight difference of the scattering powers of Fe and Ni for x-rays.

The present work was concerned with elucidating the superstructure of Ni_3Fe and determination of the concentration range over which it exists by new experimental methods. Neutron structure analysis was applied to large single crystals taken from melts of Fe-Ni alloys, as well as from ternary alloys in this series which show permalloy properties. The method used provided greater intensity and sensitivity (the latter by an order of magnitude) as compared with a Debye-Scherrer neutron structure analysis method for work with the Ni_3Fe superlattice.

The results obtained show that the concentration range over which the superlattice forms in the Fe-Ni composition diagram is markedly asymmetric about the stoichiometric Ni_3Fe composition, being wider on the iron-rich side. No superlattice was found in Ni_3Fe . It was found that the addition of elements of different types—chromium and copper—to the alloy, exerted essentially different effects on the superlattice formation process in Ni_3Fe . The data analyzed show that the ordering energy in Fe-Ni alloys is to a considerable extent ferromagnetic in type.

Fresh data were also obtained on the temperature dependence of the superlattice reflections, on the sizes of the more highly ordered regions and also some other data relating to this series of alloys.

Central Ferrous Metallurgy Research Institute.

EFFECT OF NEUTRON IRRADIATION ON THE MARTENSITE TRANSFORMATION

O. P. Maksimova and A. I. Zakharov

This paper describes an attempt to use neutron irradiation as a method of altering the state of the parent phase in advance, by causing a definite change in its stability and in the subsequent phase transition kinetics. The effect of previous neutron irradiation on the kinetics of the martensite transformation in number of steels and iron-base alloys was studied.

It was found that irradiation produces an important effect on the capacity of austenite to go over to martensite on subsequent cooling. This stability change appears as a change in the martensite point and in the final effect of the transition, the nature of the change being different in the various materials, and having much in common with changes due to previous plastic deformation.

For example, irradiation of nickel and manganese steels increases the rate of the martensite transformation, raising the martensite point and increasing the effect of cooling. In iron-nickel-manganese alloys, irradiation stabilizes the austenite, reducing the martensite point, and decreasing the effect of the transformation. Thus, the particular effects produced with the various materials by irradiation coincides, in the main, with the behavior observed, as due to deformation (the austenite stability changing in the same direction).

It was shown that prolonged storage and low-temperature (100°) annealing of the irradiated specimen leads to raised austenite stability. This effect of storage and low-temperature annealing appears as a gradual loss of the activating effect of irradiation on steels (just as occurs with relatively small deformations), while in iron-nickel-manganese alloys, the austenite stability is even more markedly raised.

An explanation is given for these results: according to this, the activation effect found in steels is caused by injection vacancies (elastic lattice deformations arising around these defects), these being known to be of low stability. The stabilizing effect of irradiation is due to the formation of more complex defects of high stability - crystallite breakdown and de-orientation occurring on irradiation.

Thus, it was shown that the use of neutron irradiation as an effective means of altering the states of materials is of interest not only as a means of altering structural states, thus producing definite changes in the properties of metals and alloys, but also as a means of studying phase transitions.

Central Ferrous Metallurgy Research Institute.

ENERGY REQUIRED FOR IONIZATION BY ELECTRONS IN GERMANIUM CRYSTALS

V. S. Vavilov, L. S. Smirnov and V. M. Patskevich

The energy E required to form an excess carrier pair (electron + hole) in germanium bombarded by electrons of energy 5-15 keV was determined.

N-type germanium crystals with p-n junctions of fused-in indium were bombarded in vacuo. E was determined from the ratio of the hole flux across the p-n junction (due to the excess pairs generated in the crystal by the electron primaries) to the flow of the electron primaries.

Surface and bulk recombination were allowed for by the simultaneous illumination with light of fixed intensity. E was found to be 3.7 ± 0.4 eV. The mean ionization energy for 5-15 keV electrons exceeded the photo or thermal ionization energy by a factor of about 5. E did not depend on the primary electron energy over a range 5-15 keV.

Lebedev Institute of Physics, Academy of Sciences, USSR.

USE OF TRITIUM TO DETERMINE HYDROGEN IN METALS

A. I. Chizhikov and V. K. Boyarshinov

The radioactive hydrogen isotope tritium was used to determine hydrogen in metals. Experiment shows that it is, in principle, possible to determine hydrogen in metals by exchange.

Further work on this topic is required, particularly as regards effects occurring in isotope exchange in gas/phase-metal systems.

STUDY OF THE PROCESS OF SINTERING IN ALUMINOUS SCHISTS

T. A. Potapova

This paper extends the study of sintering processes in aluminous charges. The diffusion of Ca^{45} in nepheline and bauxite concentrates, and the reaction kinetics of silica with limestone were studied.

The diffusion processes were studied in two ways: layer sampling, as modified by Gruzin, and by absorption. In the first case, CaCO_3 labeled with Ca^{45} was attached to the surface of a briquette, previously prepared by compressing the mineral powder before baking, while in the second case, metallic Ca^{45} was decomposed on the briquette surface in vacuo.

The diffusion parameters of Ca^{45} in bauxite were determined by the layer method for the range 1000-1250°C, and in nepheline concentrates, for 900-1150°C. The absorption method was used to determine the diffusion parameters of Ca^{45} in nepheline concentrates at 900-1200°C. Since the results obtained in the two ways were in close agreement, both methods would appear usable in any given problem.

The effect of alkaline and fluoride additives on the diffusion of C^{14} in nepheline concentrates was studied. It was found that all the additives showed a considerable effect at high temperatures, the alkaline being the most active.

The silica-limestone reaction kinetics were studied at 1000-1250°C for times of 1-6 hours. The charge composition was computed for dicalcium silicate. The temperature dependence curve showed a break due to the formation of less basic calcium silicate at low temperatures.

All-Union Aluminum-Magnesium Research Institute.

USE OF PHOSPHORUS ISOTOPES IN THE MANUFACTURE AND STUDY OF SELENIUM RECTIFIERS

N. V. Yuryev

Se^{32} and S^{32} were used to determine the layer thicknesses of cadmium selenide (sulfide) formed in the zone of contact between the selenium (sulfur) and cadmium in selenium rectifiers.

The layer thicknesses of cadmium selenide found, formed after the various operations, showed that when the temperature at which the selenium units were treated, was raised, the layer thicknesses of cadmium selenide increased. The process became more rapid as the temperature rose, reaching a maximum near the melting point.

On raising the intensity of heat-treatment at a given temperature, the layer thickness was found to rise to a limiting value, after which growth ceased.

The studies of cadmium sulfide formation conditions, and the effect of adding bromine to the selenium, showed that radioisotope methods are an effective means of improving production process control, and provide a fresh means of studying selenium rectifier processes.

Ministry of the Electronics Industry, USSR.

STUDY OF Ag-S, Sn-S AND Pb-S MELTS OF VARIABLE CONCENTRATIONS

L. S. Palatnik and G. N. Kovalev

This paper presents results on Ag-S, Sn-S and Pb-S alloys of variable composition made by simultaneous condensation of vapors of the chemically pure components on a glass collector in vacuo at $\sim (2-5) \cdot 10^{-3}$ mm Hg. The spherical evaporator distribution formula was used to find the local alloy composition (with metals) and for a circular hole (with sulfur, which was evaporated from a crucible). Comparison of the actual sulfur distribution on the collector surface with the computed figures, was carried out, using S^{32} . S^{32} was also used to check the constancy of composition in the specimen on annealing.

It appeared to be a general feature of these systems that the vapor-solid transition passes via a metastable (supercooled) liquid phase, as is shown by the vitreous areas in the layers over a definite concentration range in metal-sulfur melts. In Ag-S and Sn-S melts, which have regions of liquid-phase stratification on the stable diagrams, effects are observed which can be explained by extension of the stratification region on supercooling. The stable diagrams for these two systems are completed by lines of metastability which delimit the region of stratification into two liquid (vitreous) phases. The curves of metastability were drawn up from x-ray data.

Gorky University, Khar'kov.

II. MACHINE BUILDING, CONTROL OF TECHNOLOGICAL PROCESSES, CONSTRUCTION OF APPARATUS, METHODS AND APPARATUS FOR THE RADIOMETRY AND DOSIMETRY OF NUCLEAR RADIATIONS

USE OF RADIOACTIVE ISOTOPES IN MACHINE CONSTRUCTION

V. I. Dikushin

This report deals with the general question of using radioactive isotopes for research on wear of machine parts and of cutting tools.

Data on methods are given, obtained from study of cutting-tool wear, and prospects of further investigation are reviewed.

Metal-Cutting Machine Experimental Research
Institute

THE STRUCTURE AND ABRASION RESISTANCE OF CEMENTED STEEL

L. S. Palatkin, I. M. Lyubarsky, A. P. Lyubchenko and V. G. Nesterenko

Some aspects of the formation of wear-resisting structures in the cemented layer of alloy steel were studied using radioactive isotopes, x-ray analysis and other methods: an explanation for the experimental data is proposed.

The various modes of tempering the cemented layer as normally produced were studied. A heat-treatment cycle leading to raised γ -phase content and hence increased wear-resistance was established. A characteristic feature of this is reduced treatment time (as compared with the serial mode).

The wear of layers treated by this method was reduced, and metal transfer to the cut surface was practically absent, as well as austenite decomposition in the active friction zone.

The carbide phase formation mechanism was studied. It was found that carbide $(Fe, Cr, W)_3C_4$ was formed during cementation, while $(Fe, Cr, W)_3C_4$ was formed over the recrystallization range during cooling. A high rate of cooling after cementation retarded diffusion processes which transfer alloying elements between phases of the cemented layer, producing a marked deviation from their equilibrium concentrations in the carbides and solid solutions of iron.

Autoradiography was used to study the course of the intermediate changes in the cemented layer. The carbon redistribution in the austenite was found to occur over the whole grain body over regions of linear dimensions not greater than about 10^{-4} cm.

Harmonic analysis of the interference maxima shapes showed that the short method of treating the γ -phase caused practically no crystallite break-up, the lattice deformation being comparatively small.

Various views as to the nature of the phenomena occurring in this case are discussed. The heightened wear resistance of the cemented layer is facilitated by the high saturation of the iron solid solution with alloying elements and by the formation of a heterogeneous system of "regularly" coupled crystal lattices (austenite-martensite-carbide).

Kharkov Transport Machine Construction Works.

STUDY OF THE ABRASION OF HIGH-STRENGTH CAST IRON

V. I. Stetsenko and E. A. Markovsky

The use of a new material—high-strength cast iron with sphenulitic graphite—in the USSR autotractor industry requires that its wear-resistance be studied.

Wear and frictional processes in high-strength cast irons of varied structure were studied as functions of the frictional pair regimes at the Machine Operation Institute of the Academy of Sciences, Ukrainian SSR.

The work was carried out with specially built equipment: the wear of the pair was measured while working in oil by radioactive isotope methods, and the changes in the frictional torque were recorded at the same time on an oscillograph.

During development, the errors in measuring the radiation intensity from the radioactive products of wear using various assay units were determined.

It was shown that radioactive isotope methods could be used to estimate wear in unlubricated friction.

Data were obtained from which the best frictional pair for particular cases of specific pressure and sliding speed could be determined.

Institute of Machine Operation and Agricultural Mechanics, Academy of Science, Ukrainian SSR

STUDY OF THE SULFIDED LAYER IN WEARING PROCESSES

V. E. Vainshtein and Yu. Vinogradov

The behavior of sulfided specimens (Sch-18-36 cast iron, steel type 45), S^{35} -labelled, was studied under wear in an MI friction apparatus.

Study of the sulfided layer in wearing processes was carried out with different modes of lubricant (kerosene) feed, as well as without lubricant.

Data were obtained on the depth distribution of sulfur, on the sulfide layer regeneration during abrasion, and on sulfur transfer between the rubbing surfaces.

The sharpest fall in sulfur content with depth was found in the surface layers, these being the main areas of sulfide.

It was found that with various frictional modes at the sulfide surfaces, the sulfur remained in the frictional surfaces, and the depth of the worn layer then exceeded the original depth of sulfidation. The sulfide layer regenerated may be supposed to be due to the high temperature and deformation development at the contact areas by the friction, and to be a diffusion-type effect.

Institute of Machine Operation, Academy of Sciences, USSR

STUDY OF THE TRANSFER OF METAL DURING FRICTION AND WEAR

G. M. Zamoruev and Ya. N. Levin

Work in the metal-working and heat-treatment dept. of the Magnitogorsk Institute of Ferrous metallurgy has shown that wear of steel may take different forms, depending on the frictional conditions and on the composition and structure of the steel. Radioactive tracers were used to study metal transfer in different wear types and to compare it with the rate of surface destruction.

The method used was as follows: Fe^{59} was introduced into the liquid steel, this being poured as billets of weight about 2 kg and specimens were taken from these Fe^{59} (with carrier iron) was introduced by electrolysis into the wearing surfaces of the specimens taken. Inactive specimens were made from rolled steel of the same composition.

These specimens, and others, were given varied heat-treatments to reproduce various forms of wear.

The abrasion was carried out in MI-1 and MI-3 friction machines at the Magnitogorsk Institute of Ferrous Metallurgy. One of the parts in a frictional couple was radioactive. The metal transfer from the active to the inactive part could thus be counted and radiographed after each mode of wear.

The wear of steel in the forms reproduced was shown to be accompanied by metal transfer, but the degree of transfer differed in the various forms of wear.

The depths to which the radioactive phosphorus and iron penetrated into the surface layer, and their surface distribution after various types of wear were determined.

The relation of radioactive phosphorus and iron transfer to a number of external factors (forces at contact areas, friction path, lubrication) were studied, and possible routes of metal transfer considered.

G. L. Nosov Institute of Ferrous Metallurgy, Magnitogorsk

STUDY OF WEAR DURING ROLLING FRICTION

V. P. Pavlov, G. V. Vinogradov, Yu. S. Zaslavsky and F. B. Lebedeva

The methods available for studying wear during rolling friction differ greatly in the time required. Radioactive tracer methods were used to provide a short-cut.

Wear studies were carried out on a special four-ball friction machine, the working part of this being a model no-separation radial-thrust ball-bearing. Fe^{59} was produced in one ball by neutron irradiation. Oil samples were taken periodically from the working chamber with a syringe and assayed in γ -ray counters.

The method was used to determine ball-wear dynamics during rolling friction at 30-40 hours, when the results were of satisfactory reproducibility.

All-Union Research Institute for Oil and Gas
Reworking and Artificial Liquid
Fuel Production, and Heavy Tank Formations
Military Academy

A SCINTILLATION COUNTER FOR THE MEASUREMENT OF RADIOACTIVITY
IN LIQUIDS

O. E. Kalinovskiy

The circuit is given of scintillation equipment, developed at the Central Diesel Research Institute for measuring γ -rays from wear products present in lubricating oil.

The main technical data are given, together with a comparison of measuring heads using scintillation and Geiger-Müller counters.

Central Diesel Research Institute

RELATION OF THE PISTON RING AND CYLINDER LINING WEAR TO THE
SPEED AND MAXIMUM PRESSURE IN THE CYCLE

M. D. Nikitin

Relation of the piston ring and cylinder lining wear to the speed and maximum pressure in the cycle was studied with radioactive tracers on a 5/11 Ch8 diesel.

The working parts were activated with traces of Co^{60} , and wear was determined from oil samples, using a scintillation counter.

It was shown that there was an optimum rpm (1500 rpm in this case) at which wear was least. The cause of increased wear at lower rpm was a worsening in lubrication conditions.

The test results show that raising the maximum cycle pressure (P_z) causes increased wear in the cylinder/piston assembly, particularly in the piston rings.

Central Diesel Research Institute

STUDY OF THE EFFECT OF DUSTING ON THE WEAR OF PARTS OF A
TRACTION MOTOR

A. I. Nisnevich

The wear resistance of tractor couplings is determined at present from field experiments which depend on the climatic conditions and which last, as a rule, for 1-2 agricultural seasons.

In order to reduce the test times for new materials and links, an accelerated test-bed method is required, based, in particular, on experiments with artificial dusts and the use of radioactive isotopes to measure extremely small degrees of wear.

Laboratory tests of wear in various antifriction metals (cast iron, bronze, aluminum alloys) paired with heat-treated steel were carried out to solve this problem. The tests were performed with varying amounts of natural dust in the lubricating oil, as well as with dusts taken from a turbo-gas generator operating on various fuels.

The rate of wear was shown to rise rapidly with the mechanical impurity content, being a function of the fractional composition and physical properties of the dust.

Rise in the organic content of the dust caused a fall in the maximum wear.

The bench tests were done with a D-54 motor, this being the one most widely used in agriculture, artificial dusts and radioactive isotopes being used to measure wear, and a relation between the amount and fractional composition of the dust and the rate of compression-ring wear was established.

In particular, the greatest compression-ring wear occurred when the intake air contained particles of mean diameter 10-20 μ (silica content about 80%).

This method was used to study two forms of tractor engine air filter. When the engine was operated with a new three-stage air filter, developed at the Tractor Research Institute, the rate of compression-ring wear was reduced by about a factor 3.

Tractor Research Institute

STUDY OF THE EFFECT OF OIL QUALITY ON THE WEAR OF CAST IRON

V. S. Zavel'sky and K. S. Ramalya

Oil quality affects the wear of rubbing surfaces, and the wear also depends on the metal pair, the temperature, pressure, frictional velocity etc. The external medium also affects the wear-inhibiting action of the lubricant to a considerable degree. An actively corrosive gas medium may sometimes raise and sometimes reduce the wear, depending on the quality of lubricant used.

Wear of the cylinder/piston assembly in an engine occurs under high temperature and low pressure conditions with a corrosive - gas medium.

A laboratory apparatus RM-NAMI, was produced which was convenient for studying the effect of oil quality on wear of cast iron and other metals and alloys under conditions simulating those of the sliding surfaces in an engine. A special feature of this equipment is that high temperatures can be produced at the rubbing surface while the oil body temperature is comparatively low, and that experiments can be carried out with a corrosive - gas medium. Radioactive isotope methods were used to measure wear, the sensitivity being of 0.005 μ order.

Comparative tests of specimen oils in RM-NAMI and in a real engine showed that the relative estimates of oil anti-wear efficiency were the same in the two units.

The effect of oil contamination and the gas medium on the wear were studied.

The primary action of organic impurities which accumulate in the oil as a suspension was shown to reduce the wear, while the accumulation of oil-soluble compounds increased the wear.

Sulfur dioxide, which is one of the fuel combustion products in an engine, was shown to affect not only the acid corrosion at low temperatures (by combination with water) but also the gaseous corrosion at high temperatures. The SO_2 also reacts with the lubricant to give products which protect the cast iron surface at the same time.

When high-sulfur fuels are used, the resultant of the two opposing processes (gas corrosion and protective action) produced by the SO_2 may be increased wear.

Automobile and Automotor Research Institute

REDUCTION OF LOW-TEMPERATURE WEAR IN A CYLINDER/PISTON GROUP OF MOTORS BY USE OF OIL SUPPLEMENTS

Yu. S. Zaslavsky, G. I. Shor and I. A. Morozova

The low-temperature corrosive wear of the cylinder/piston assembly due to the cooling water, which is a very notable feature of vehicle fleet operation, can be effectively reduced by adding special materials to the engine oil. The mechanism by which these materials act has been inadequately studied however.

Radioactive rubbing parts were used in a friction machine to study the mechanism by which these additives act, this providing automatic wear recording.

Vapors from acid solutions (sulfuric, acetic, formic) introduced into the machine sump condensed partially on the rubbing surfaces, which thus stimulated the operating conditions in an engine cylinder at low working temperatures. A large number of engine oil additives was studied, and the following conclusions were arrived at.

1. The basic cause of wear of rubbing surfaces operated in an atmosphere containing acid vapors is electrochemical corrosion.
2. Protection of the rubbing surfaces from corrosive wear is produced by oil additives with the following properties:
 - a) acid-neutralizing capacity, due to a metal of chemical activity greater than those in the rubbing surfaces present in them.
 - b) capacity to react chemically with the metal rubbing surfaces and thus to form a product protective layer while simultaneously reducing the coefficient of friction and hence the erosive wear.
3. The most promising additives which act by neutralization are soaps of metals which give water-soluble salts with the attacking acids, and thus exert no abrasive action on the rubbing surfaces.

All-Union Research Institute for Oil and Gas Reworking and Artificial Liquid Fuel Production

STUDY OF THE MECHANISM BY WHICH ANTI-CORROSION ADDITIVES IN OILS ACT

Yu. S. Zaslavsky, S. E. Krein and R. N. Shneerova
G. I. Shor

To protect internal-combustion engine bearing bushes from corrosion, anti-corrosion additives are included in the engine oil: these act by forming protective sulfur or phosphorus layers on the metal surfaces.

Radiochemical methods have been used to follow up the relations between tendency to give protective layers, the layer stability relative to the destructive action of oxidation products from the oil, and the rate of corrosion.

Various sulfur or phosphorus-labelled organic compounds were studied.

The simultaneous study of the kinetics of protective layer formation for lead sheet surfaces and of lead corrosion showed that all the sulfur and phosphorus compounds used gave protective layers on the lead surface, retarding corrosion by oil oxidation products.

The effect of various high molecular weight organic acids on the kinetics of protective layer formation by anti-corrosion additives and on the kinetics of lead corrosion was studied. To increase the efficiency of anti-corrosion additives it was shown to be desirable to choose compounds which, when introduced into the fortified oil, would exert a polishing action on the metal but would not cause destruction of the oil.

In this connection it was shown that when acid products accumulated in the oil beyond some definite limit (different for each acid) the oil additives were destroyed and their anti-corrosion action lost.

The anti-corrosion action of added tributyltrithiophosphate, both sulfur- and phosphorus-labelled, was studied. When tributyltrithiophosphate was used it was shown that both the sulfur and phosphorus were initially active in preventing corrosion, but later only the sulfur was active.

All-Union Research Institute for Oil and Gas
Reworking and Artificial Liquid Fuel Production

STUDY OF THE MECHANISM BY WHICH OIL ADDITIVES REACT WITH METALS

M. M. Kusakov, G. V. Vinogradov, E. A. Razumovskaya, P. I. Sanin
and A. V. Ulyanova

The choice of lubricating oil anti-wear additives requires that the reactions of active oil components with metals be studied as well as their operating temperature limits, and that the role of the oil itself be elucidated. Interesting results bearing on the solution of this problem were obtained with S^{32} - and P^{32} -labelled thiophosphoro-, and phosphoro-organic compounds reacting with metals, the compounds being dissolved in a naphene-paraffin oil fraction type MS-20.

Study of the reaction kinetics for oil containing an S^{32} -labelled additive and steel at various temperatures showed that the metal began to react with sulfur compounds of the sulfide and disulfide types only at about 120-140° C. Disulfide type compounds appeared more active with respect to the metal than did the sulfides. Results obtained with added elementary sulfur and thio-organic compounds showed that the greatest reactivity with regard to the metal was found in compounds in which the sulfur was most labile.

Reactions of the metal with phosphoro-organic compounds (e.g. tributylphosphite) as additives showed that they began to react even at room temperature, and react much more rapidly at 150-160° C with rapidly rising decomposition. Similar results were obtained with tributyltrithiophosphate, phosphorus-labelled, showing that the phosphorus is easily bound to the metal surface, while the part of the molecule containing the sulfur is evidently split off.

The data on the interaction of oil additives with metals agree with results from anti-wear tests with thiophosphoro-organic compounds and with mixtures of thio- and phosphoro-organic compounds, from which one may assume that under moderate frictional conditions (seizing and sharp temperature rises absent) the phosphorus has the main influence in hydrocarbon solutions of thiophosphoro-organic compounds and mixtures of thio- and phosphoro-organic compounds.

Oil Institute, Academy of Sciences, USSR

STUDY OF DRIVE WEAR IN COAL MACHINES

E. Ya. Studnits

Until now there has been no adequately sound method of selecting lubricating oils for gear wheels, so the oil to lubricate the reduction gear in coal-cutting machines has had to be wear-tested.

A radioisotope method of measuring gear-wheel wear has been developed. Pinions were activated with added Zn^{65} . The pinions worked in a reduction gear with an oil circulation system containing a γ -counter. The tests lasted 10-20 hours.

The use of radioactive tracers for studying relative pinion wear when working in various oils under different conditions was found most efficient, and gave reliable data within short periods.

All-Union Coal Research Institute

STUDY OF METAL-CUTTING PROCESSES

N. F. Kazakov

Cutting-tool wear resistance determinations using radioactive isotopes gave a simple relation between the transfer of cutter material to the work-piece, the shavings and the coolant and the cutting time, as well as the specific wear of the tool, the speed, depth of cut and the feed; from which some quick tests were devised to determine the tool cutting properties, the machinability of the material, coolant efficiency, etc.

The method was shown to be applicable and accurate even when the wear time was 2-3 hours, so the time required for a test was reduced by a factor of 25 or more, as compared with micrometric methods.

It was shown to be more efficient to activate the parts when studying friction and wear along the contact of the tool with the chip and the work piece, since the deposit accumulates on the tool. In addition, many nonradioactive tools could be used in this method, and the relation of the cutting process to the various factors could be studied.

Both the qualitative and the quantitative aspects of wear could be evaluated from the data obtained, and thus the type and nature of cutting-tool wear could be discovered, beginning with conditions under which adhesive and diffusive interactions occur, with metal transfer from tool to work-piece and vice versa. Hence it became possible to select operating conditions in which wear resistance was greatest and thus the working time in cutting was higher.

Institute of Machine Operation, Academy of
Sciences, USSR

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Institute of Machine Operation, Academy of
Sciences, USSR

STUDY OF WEAR IN HARD-ALLOY SCREW-CUTTING TOOLS

B. D. Lazebnik

New theories of weight loss and wear in cutting tools were derived by using radioactive isotopes to study wear in cutting tools: a new method of accelerated determination of the resistance as a function of cutting speed was also proposed.

Radioisotope methods are differential, unlike weighing, which is integral. The proposed loss equation is in good agreement with the available data. This equation can be used to study the stability and to set up stability criteria in the weight loss process.

The formula $G = cr^X$ is proposed as an appropriate relation between wear weight and time.

There is found to be a limiting attainable wear weight L_{max} , the tool being taken out of use on reaching this.

The experiments demonstrate the effect of cutting speed on the rate of wear.

A method of accelerated determination of the speed-resistance relation is proposed from the relationships found. Experimental tests showed that the method was usable in practice.

Institute of Machine Operation,
Academy of Sciences, USSR

A METHOD OF ESTIMATING THE DEGREE OF METAL DEGREASING

R. B. Chernyakova

This paper expounds a method of checking the degree of removal of soaps and soap-grease emulsions from metal surfaces, using radioactive isotopes.

Cs^{137} was used as a tracer, introduced as a 3N hydrochloric acid solution of test contaminant. The amount of tracer adhering to the surface used, and the amount remaining after degreasing the contamination, being proportional to the tracer activity, were determined from the number of disintegrations per unit time recorded by the counter setup.

The detector was a standard detector type B, with a γ -counter assembly. Autoradiography was used to detect tracer concentration on the surface of the object. X and XX x-ray plates were used, their resolving powers being sufficient for this purpose.

This method enables one to estimate the cleanness of the degreased surface visually and objectively with a high degree of accuracy: the amount of residual tracer can be found both relatively and in absolute units of weight.

The method sensitivity (at a given tracer specific activity) was such as to detect 10^{-8} – 10^{-6} g of contaminant.

Use of the method to check the quality of degreasing of parts in mass-production lines showed that it should be applied in working out the technology of degreasing processes.

EFFECT OF RADIOACTIVE RADIATIONS ON THE SURFACE PROPERTIES OF METALS

G. N. Meshcheryakov

The so-called bob hardness is specified by the loss on collision with a metal: the surface properties of metals after irradiation were studied using Kusnetsov's bob tester.

The work was carried out with polycrystalline zinc at a temperature above the recrystallization temperature, and also with Armco iron, aluminum, platinum, beryllium and gold. Co^{60} was used for irradiation, radiation doses of 0.02 r/min/cm² being used.

The bob hardness was found to increase by factors of 1.5–2.

The hardening effect saturated at 1 minute of irradiation, some drop in hardness then following on further irradiation, followed later by no great change.

The magnitude of the hardening effect was shown not to be connected with the lattice packing density, as is the case with intense neutron irradiation, and the bob hardness rose even in metals (Be), which do not usually react to irradiation, or which regain their initial properties (Zn, Al) even at room temperature.

A series of experiments to elucidate the physical basis of the hardening effect was carried out by irradiating in various media (O, A), by irradiation of deformed specimens, or specimens previously treated with surface-active materials, etc.

The hardening may be concluded from this to be of adsorption type and, unlike Rebinder's wedging effect, leads to healing of submicroscopic surface cracks. The healing is due to adsorption potentials arising at the mouths of the cracks and, as a consequence, there are electrostatic bonding forces which prevent removal on collision.

Experiments are described dealing with different types of mechanical tests of metals which have undergone adsorptive interactions when irradiated, e.g. from friction by cutting thin layers etc: these experiments show that irradiation with Co^{60} can be used effectively for practical purposes.

Odessa Polytechnical Institute

STUDY OF THE CAST FORMATION PROCESSES IN SAND MOLES

B. B. Gulyaev, Yu. F. Borovsky, L. M. Postnov and O. N. Magnitsky

This report deals with the use of radioactive tracers to study the formation of castings when sand molds are used.

The effect of the pouring system construction on the incorporation of nonmetallic particles which fall into the mold with the metal was studied: the most rational construction was selected.

The liquid metal-sand mold reaction was studied. It was found that the mold surface was washed off by the liquid metal and that this caused contamination of the castings. The effect of the main technological factors on the rate of this process was studied.

It was found that when the pour-off temperature was sufficiently high a solid film first formed on the casting surfaces, but then melted, and the liquid metal was in direct contact with the mold surface for some time, after which the main solidification occurred. The effects due to pour-in temperature, site of run-in and the rate of mold filling on the duration of the liquid-metal/mold surface contact were evaluated.

It was shown that the castings could be fed only within the pour-off limits, this lying between the liquidus and solidus. The effects of melt crystallization conditions on the pour-off limits were determined.

These results were used to develop measures aimed at improving the quality of castings, and the basic ways of using radioactive tracers in research on casting processes were indicated.

STUDY OF THE MECHANISMS OF THE BASIC PROCESSES IN HOT
TINNING

A. I. Vitkin

Radioactive isotopes of tin and iron were used to study the movements of these metals in a flux technic unit, to elucidate the basic mechanisms in the hot tinning of steel.

The basic processes in the flux unit were elucidated.

Central Ferrous Metallurgy Research Institute

USE OF NUCLEAR RADIATIONS FOR MEASUREMENT OF THERMAL
PARAMETERS

G. G. Jordan and K. S. Furman

The technical processes used in current industrial production continuously become more complicated and refined: the rates of operations are raised, the temperature and pressure rise, most frequently reactive and toxic

media are involved, etc. This all demands that the control and measuring gear should record and adjust the basic parameters of the processes continuously without being introduced within the units, or without the sensitive elements being in contact or communicating with the controlled media.

One way of complying with this requirement is to use the various forms of nuclear radiation. This tendency in control and measurement technic has developed strongly both in the USSR and abroad in recent years. Various control systems using the radiations from radioactive isotopes have been produced.

These systems contain four elements: radiation source, detector, electronic transformer head and secondary units. The system composed of the first two elements is termed the pick-up head, and provides an electrical signal functionally related to the controlled parameter.

Artificial radioactive isotopes are used as sources of α , β - and γ radiations and, via secondary processes, as x-ray and neutron sources.

Equipment using nuclear radiations to control the parameters of thermal power sources may be classified as follows:

- 1) those using changes in relative position of source and detector;
- 2) those using the laws of interaction between x- and γ -rays and matter;
- 3) those using the laws of interaction between β -rays and matter;
- 4) those using ionization and atomic excitation effects;
- 5) those using the laws of interaction between neutrons and matter.

Questions relating to the design of such units are considered; ways in which the use of radioisotopes in the field of thermal power source construction could be developed are indicated; constructional schemes for new units for measuring parameters such as the concentration in a liquid, the flux of a gas, moisture and hydrogen contents, composition and temperature, are considered.

Recommendations are made for the most rapid solution of problems connected with the wide use of these units.

Thermal Power Source Construction Research
InstituteMEASUREMENT OF RADIOACTIVE RADIATIONS WITH A SCINTILLATION COUNTER
A METHOD OF REDUCING THE INSTRUMENTAL ERRORS

B. I. Verkhovsky, V. A. Sotnikov and V. V. Yakushin

Equipment composed of scintillation counter plus electronic circuits are described.

In one case a special modulator unit produced an intermittent radiation flux through the scintillation phosphor, calibration being from an auxiliary source. The circuit separated and amplified the signal in proportion to the difference of these radiation fluxes. An indicator unit was attached to the output of the signal-difference measuring unit, or else a reversible drive, to the spindle of which was attached a variable-thickness wedge, which equalized the radiation fluxes falling on the phosphor. The errors in measurement with the apparatus, which are due to instability in the gain of the FEU (photomultiplier), are reduced by a factor m , where m is the ratio of flux measured to the difference between the absolute values of the measured and standard fluxes. By using the wedge arrangement changes in the FEU gain only altered the sensitivity of the unit.

In another modification of the equipment, two phosphors were used; on one fell the radiation flux being measured, while the other received the calibration flux. The light fluxes from these phosphors fell on the multiplier photocathode in turn. The relative statistical error of the measurement of radiation flux is defined by the expression

$$\delta = \frac{2}{\sqrt{n\tau}}$$

where n is the number of γ -quanta recorded per unit time;
 τ is the time-constant of the synchronous detector.

Lebedev Institute of Physics, Academy of Sciences,
 USSR

ANALYTICAL METHODS OF USING IRRADIATION

V. A. Korotkova

This report gives a short description of an activation analysis method, and of compositional analysis by radiation emitted in the absorption of nuclear particles, e.g. (n, γ), (n, α) and (n, p). The general types of analytical problems which can be solved by these methods are considered. Comparative data on the sensitivities of activation and spectral analysis are given (from literature data). Some possible regions where activation analysis is of definite use are pointed out. Activation analysis is best used in those cases where high accuracy, not available by other methods, is required in determining very small amounts of elements which have very high effective activation cross sections.

Lebedev Institute of Physics, Academy of Sciences,
 USSR

USE OF SCINTILLATION COUNTERS WITH ELECTRONIC MODULATION IN INDUSTRIAL γ -RADIATION INDICATORS

E. Ya. Ovcharenko

The problem of measuring the levels of various media within definite indicated positions is frequently encountered in the recording and automatic control of industrial processes.

The γ -rays from radioactive isotopes can be used to good advantage in level indicators by passing them through the space to be examined.

All units of this type described in the literature use gas-discharge counters as γ -ray detectors. The γ -ray efficiency of these is low ($\sim 0.1\%$), and so the source activity becomes impractically great when the source-detector distance is great or when there is much absorption in the walls of the container.

We developed a scintillation counter/transistor amplifier unit. The high γ -ray efficiency of scintillation counters reduces the required source activity by powers of ten and, by combining these with semiconductor components, convenient operation is provided.

The gain was raised by applying low-frequency electronic modulation to the multiplier.

Various methods of electronic modulation were tested. The most convenient and direct was to supply the multiplier with pulsed voltages.

Examples of the use made of this unit in level indicators in subterranean bunkers (ore chutes) and in metallurgical electric shaft furnaces are given.

"Light-Metal Automation" Design Bureau

USE OF RADIOACTIVE RADIATIONS FOR THE CONTACTLESS MEASUREMENT OF THE DISCHARGE AND VELOCITY OF A GAS

N. N. Shumilovsky and L. V. Mel'tser

The methods of measuring gas discharge or speed with radioactive isotopes can be divided into two groups.

Amplitude, or relative, methods. When the discharge (speed) alters, the signal amplitude applied to the measuring unit changes. The following methods belong to this group.

a) Ion loss method.

Two electrodes are placed in the flow, joined in series to a power source and the measuring head. A layer of radioactive material is deposited on one electrode, the radiation from this ionizing the space between the electrodes. The greater the flow speed, the fewer ions reach the electrodes and the lower the current in the circuit.

b) Ion recombination method

An electrode coated with a layer of radioactive material is placed higher up the flow, while the other is below it. The current in the circuit of the second electrode is measured. The lower the flow rate, the more ions recombine during the interelectrode transfer time and the weaker the current.

There is a typical dependence of readings on external factors and the state of the gas medium in all amplitude methods. Use of balanced circuits with the electrodes improves matters somewhat, but complete independence is not attainable. The electrodes must also be electrically in contact with the flow.

Time, or absolute, methods. The time taken to transfer some volume of gas through a fixed distance is measured. The readings then do not depend on external factors. The following methods belong to this group.

a) Atomic tracer methods, in which a small volume of radioactive gas is injected via a probe at some point in the flow. The transfer time for the labelled region is measured over a fixed distance. The method is not very applicable to automation, requires a continuous flow of radioactive material and contaminates the gas flow.

b) Molecular tracer methods. A given area of the pipe is irradiated by a chopped plane beam of radioactive radiation. Ion clusters are produced within the tube and the transfer time for the labelled region is measured over a fixed distance. The source and receiver are completely isolated from the flow. There are no measuring probes within the flow. The measurement can be repeated tens of times a second, which facilitates continuous remote control of the discharge of gas speed by means of very simple regulators.

The measuring heads for the molecular tracer method are described, and results from experimental and theoretical studies of the methods are given.

The results show that this method has definite advantages over others.

Institute of Automation and Remote Control
USSR Acad. Sci.

AN APPARATUS FOR AUTOMATIC GAS-FLOW MEASUREMENT USING B-RAYS

G. G. Iordan, K. S. Furman and T. G. Neiman.

In most cases discharge meters based on pressure drop are used to record discharged gases, the drop being produced by constrictions (diaphragms, nozzles etc.) inserted in the pipe. The constrictions cause a pressure drop in the flow, which makes it difficult or sometimes impossible to use these discharge meters at low gas speeds. When abrasive or corrosive gases are to be metered it is undesirable that the constrictions should be in contact with the measured medium (the rapid wear of diaphragm edges produces undesirable errors). In addition, the nonlinear relation between efflux and pressure drop makes the measurements inconvenient and produces difficulties in totalizing effluxes.

Thus, it is urgently necessary to seek new and more refined methods of gas efflux metering.

One refined way of solving this problem is to use the radiations from radioactive isotopes.

An experimental model of a radioactive gas flux meter for general industrial use was produced in 1956; this gives continuous remote readings, recordings and control of the flows of various gases without pressure loss in the flow.

The basic concept used was proposed by Shumilovsky and Meltser. The method is based on measuring ion packet transfer times, the ions being produced by radioactive emissions.

When the ion source-receiver distance is constant, the transit time is inversely proportional to the mean gas speed, and thus to the volume flux in a pipe of constant cross section.

A self-balancing circuit for gas flux metering, having a linear scale and high accuracy of measurement, was developed.

An experimental model of such a unit is at present on test under factory conditions.

Research Institute for Thermal Engine Construction

USE OF RADIOACTIVE ISOTOPES FOR AN AUTOMATIC CONTROL OF LIQUID FLOWS

N. N. Shumilovsky, Yu. V. Gushchin and M. I. Tolokonnikov

Existing methods of measuring liquid flows have a number of basic faults: the measuring probes are in direct contact with the medium, the resistance inserted is large: Pitot flow meters cannot give distant readings or recordings, etc. All these shortcomings become particularly important in automatic control of highly corrosive or hazardous liquids, or liquids under high pressure.

Methods which do not require that the measuring probes are in direct contact with the medium are of great interest. Those automatic control methods using radioactive isotopes occupy an important place among them.

Mechanical modulation of the emission from the radioscope was used in developing an automatic liquid flow meter: a completely isolated, coated vane rotated in the liquid. The calculations on the choice of radioactive isotope activity, and the experimental studies, showed that it was quite possible to pick up the pulses on the receiving unit and to measure the pulse frequency (liquid flux) and number of pulses (amount of liquid) at different pipe-wall thicknesses.

The liquid flux meter was made up of two main units: the pick-up and the measuring head proper. The pick-up was made in two different forms. A Geiger-Muller counter was used as detector in the first form; a scintillation counter was used in the second. The emission from Co^{60} distributed on the vane was modulated at the rotation frequency. This, picked up by the receiver, was transformed to an electrical signal (voltage pulses of definite frequency), this being fed to the measuring head, which recorded both the instantaneous liquid flux (via meter reading or automatic recorder) as well as the total liquid passed (on a scaler).

The test of an experimental unit under production conditions confirmed that it was quite possible to use this method to measure the flux and total flow of liquid in a pipe.

Institute of Automation and Remote Control
Academy of Sciences, USSR

MEASUREMENTS OF THE CONCENTRATIONS OF SOLUTIONS BY MEANS OF B-RAYS

G. G. Iordan and T. G. Neiman

The new methods of determining concentrations, which are based on the laws of β -ray absorption and scattering in matter, enable one to perform continuous adjustment of technical processes. Concentrations were determined using the β -rays from radioactive materials and an experimental type of unit for general industrial use in continuous remote measurement, recording and control of the composition of a binary liquid mixture was produced, this involving the introduction of no measuring probes into the vessels.

The measuring heads for the molecular tracer method are described, and results from experimental and theoretical studies of the methods are given.

The results show that this method has definite advantages over others.

Institute of Automation and Remote Control
USSR Acad. Sci.

AN APPARATUS FOR AUTOMATIC GAS-FLOW MEASUREMENT USING B-RAYS

G. G. Iordan, K. S. Furman and T. G. Neiman.

In most cases discharge meters based on pressure drop are used to record discharged gases, the drop being produced by constrictions (diaphragms, nozzles etc.) inserted in the pipe. The constrictions cause a pressure drop in the flow, which makes it difficult or sometimes impossible to use these discharge meters at low gas speeds. When abrasive or corrosive gases are to be metered it is undesirable that the constrictions should be in contact with the measured medium (the rapid wear of diaphragm edges produces undesirable errors). In addition, the nonlinear relation between efflux and pressure drop makes the measurements inconvenient and produces difficulties in totalizing effluxes.

Thus, it is urgently necessary to seek new and more refined methods of gas efflux metering.

One refined way of solving this problem is to use the radiations from radioactive isotopes.

An experimental model of a radioactive gas flux meter for general industrial use was produced in 1956; this gives continuous remote readings, recordings and control of the flows of various gases without pressure loss in the flow.

The basic concept used was proposed by Shumilovsky and Meltser. The method is based on measuring ion packet transfer times, the ions being produced by radioactive emissions.

When the ion source-receiver distance is constant, the transit time is inversely proportional to the mean gas speed, and thus to the volume flux in a pipe of constant cross section.

A self-balancing circuit for gas flux metering, having a linear scale and high accuracy of measurement, was developed.

An experimental model of such a unit is at present on test under factory conditions.

Research Institute for Thermal Engine Construction

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Institute of Automation and Remote Control
Academy of Sciences, USSR

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The β -ray back-scatter coefficient is related to the atomic number of the material in the scatterer by the approximate law Z^n , where $n < 1$ and is dependent on the source-scatterer-detector configuration.

The ionization-chamber current produced by the β -particles scattered by the binary liquid mixture was given approximately by the following expression:

$$I = I(Z_1) C_1 + I(Z_2) C_2 - I(Z_2) + C_1 [I(Z_1) - I(Z_2)],$$

where $I(Z_1)$ and $I(Z_2)$ are the currents due to back-scattering by the separate components of the mixture C_1 and C_2 are the concentrations by weight of the components ($C_1 + C_2 = 1$).

Since the chamber current was directly proportional to the concentration of either of the mixture components, the scale of the β -ray concentration meter was linear.

A formula defining the sensitivity of the method is given. The choice of radiation source intensity and system geometry is based on this. Data are given for the maximum sensitivity in determining the concentrations of solutions of differing chemical composition which is attainable by using a current-measuring unit with a threshold sensitivity $5 \cdot 10^{-12}$ amp. Ways of increasing the accuracy still further when measuring concentration of a binary liquid mixture are given, as well as the principle on which it would be possible to determine the concentrations of two components in a ternary mixture simultaneously.

Research Institute for Thermal Engine Construction

SOME QUESTIONS IN THE CONSTRUCTION OF γ -RAY LEVEL GAUGES

V. K. Latyshev, V. V. Lyndin, S. V. Medvedev, Yu. S. Pliskin, L. K. Tatchenko and V. I. Shulga

A new no-contact method of measuring levels of liquids, fused metals, loose materials, etc., contained in closed vessels has recently been widely applied in a number of branches of technology. The measuring equipment is composed of a γ -ray source and detector with a special electronic circuit. All γ -ray level indicators use the differences in γ -ray absorption of the media on the two sides of the bounding surface.

The report deals with the functioning of gas counters in an average current mode, and simple relations between the mean current, the applied voltage and the counter load are obtained.

Three types of level indicators are described:

- 1) follower-type γ -ray level indicators;
- 2) γ -ray level indicators working as intensity meters;
- 3) relay-type γ -ray level indicators.

Finally, the use of γ -ray level indicators as level detectors in control systems is considered, and one existing system of automatic level control for liquid metal is described which uses a level measurer of relay type.

Central Ferrous Metallurgy Research Institute

USE OF RADIOACTIVE ISOTOPES IN ACCIDENT PREVENTION

I. S. Reizen and V. C. Medvedeva

1. Static electricity has to be dealt with in many branches of industry, since it increases the fire hazard and prevents faster operation of machines.

In some cases grounding, moistening, etc., can be used to deal with static electricity, but in most cases and particularly when the charge is produced on insulators, there have until recently been no really effective means of dealing with it.

The use of radioactive radiations, e.g. from Po^{210} , Pu^{239} , Ti^{204} and Sr^{90} , to neutralize the static charge by ionizing the air has given very good results, charges at 50-100 Kv being neutralized under industrial conditions.

The radioactive isotopes were attached to metal backings and used as sources of local ionization in the region where the static charge formed.

Studies on the use of α - and β -rays for bulk ionization of air were carried out.

2. Development of emergency trips.

All existing emergency trips only reduce the injury, none eliminating it completely.

We developed emergency trips for rollers, using radioactive isotopes, which conveniently enabled us to prevent crushing of the worker's hand when work was done in the hazard zone. The radiation detectors were STS-6 and STS-8 counters. The radiation source (a very small amount of Sr^{90}) was enclosed in a capsule attached to the workers hand. The circuit worked stably and justified the method.

Moscow Chemical Engineering Institute

EXPERIMENTS ON THE USE OF RADIOACTIVE ISOTOPES FOR REMOVING STATIC CHARGES IN THE SILK INDUSTRY

P. L. Polonik, L. V. Meltsner and N. I. Panyukov

With the use of synthetic fibers (caprone, chlorin, anid, etc.) in the textile industry, trouble with static electricity has increased sharply, due to the marked tendency of these fibers to become electrified during processing.

The report deals with the use of α - and β -rays to remove the static charges in the warping of caprone.

It is shown that, although the most convenient air ionization source for dealing with static charges is one of α -rays, in some cases soft β -rays can be used with advantage. In particular, soft β -rays (Sr^{90}) were used to deal with static charges in the Shcherbakov combine. The difference in ionizing capacity of α - and β -emitters is evaluated.

A table showing the efficiencies of the various irradiators is given, and a method of computing the activities in them is described.

A criterion of the efficiencies of the various irradiators is given as the product of the charge density and the rate of strip movement and width.

Silk Industry Central Research Institute

MEASUREMENT OF LIQUID DENSITY WITH γ -RAYS

G. G. Jordan and K. S. Furman

The continuous remote measurement and adjustment of the fluid density in a current without inserting a control pick-up in the flow and without the measuring element being in direct contact with the medium measured, are possible by using the γ -rays from radioactive isotopes. The first method is based on the change in γ -ray intensity on passing through the medium. The second method is to determine the changes in scattered γ -ray intensity due to the measured medium.

Circuits for measuring the density by both methods are given in the report: the γ -ray intensity/fluid density relation is considered for narrow and wide beams, and estimates of the sensitivity are given.

It is shown that most problems involving measurement of fluid densities in production units can be solved by using γ -rays from Co^{60} , Cs^{137} or Cs^{134} , and that the chemical composition of the fluid is such that the mass absorption coefficient is defined by the expression

$$\mu = C \sum_k P_k \left(\frac{Z}{A} \right)_k,$$

where P_k is the concentration by weight.

$\left(\frac{Z}{A} \right)_k$ — the atomic number/atomic weight ratio for the k -th component;
 C is the coefficient dependent on the energy of the radiation.

The questions of accuracy and response time in industrial equipment for density measurement are analysed in the report, and the advantage of using self-balancing circuits and scintillation counters or ionizing chambers as radiation pick-ups.

The PZhr-2 and PZhr-3 fluid densitometers, which work in the 0.2-0.3 g/cm³ range, are described: these measure the fluid density with an error not greater than $\pm 1\%$ over the working range. These units are undergoing detailed industrial test in the food and chemical industries at the present time.

Research Institute for Thermal Engine Construction

A NEW TYPE OF RADIOACTIVE DENSITOMETER

G. I. Birger, B. I. Verkhovsky and E. Ya. Ovcharenko

There are a number of important shortcomings in the equipment and methods used at the present time to measure the densities of metallurgical slimes. Many of these faults may be removed by using γ -ray absorption methods to determine the pulp densities. Change in the mineral make-up of the pulp does not result in appreciable errors if γ -rays of energy around 1 Mev are used.

To reduce errors due to radiation detector and circuit instability, balance methods were used for measurement in the unit developed. The radiation detector was a scintillation counter (photomultiplier type FEU-19). Two γ -ray sources were used in the unit (Co^{60} of activity 10 and 2 mc). The rays from the main source passed through the pipe carrying the slime, while those from the second (balancing) source fell on a phosphor after passing through a driven wedge of variable thickness. The radiation sources were fixed to the armatures of electromagnetic vibrators. The relative phases of the vibrators were made such that the γ -ray fluxes from the main and balancing sources fell on the phosphor in turn. When the fluxes were unequal, a signal was produced in the circuit which caused the reversible motor to rotate, the output shaft being attached to the balancing wedge, which latter made the two fluxes equal. The wedge position was transmitted to a dial instrument, and was used to indicate the pulp densities.

Lebedev Institute of Physics, Academy of Sciences,
 USSR

SOME QUESTIONS IN THE INDUSTRIAL MEASUREMENT OF DENSITIES WITH γ -RAYS; γ -RAY DENSITOMETERS FOR DREDGING EQUIPMENT

E. G. Kardash

The laws of γ -ray absorption in mixtures are considered, including mixtures containing water or other hydrogen components. The possibility of measuring the content of a component by γ -ray extinction and the accuracy of the method of density measurement are analysed. The choice of isotope and activity is dealt with, as well as the optimum γ -ray beam direction when measuring the densities of media present in tubes of large or small diameter, and also the choice of radiation detector. It is shown that gas-discharge counters can be used as detectors only when a long measuring time (time constant) is permissible, or when the accuracy of measurement required is not high. The time constant may be materially reduced (or the accuracy raised) by raising μ (i.e. the linear attenuation factor: μ is the γ -ray path length in the mixture), i.e., by using isotopes with soft radiations or by increasing x (e.g., by directing the γ -ray beam obliquely, if the source strength is simultaneously raised).

Units for measuring the soil percent in a water/soil mixture are described. These are applied to suction-dredge instruments, and the results of two-year test and use on dredgers are given. Some new units of this type are dealt with briefly, including those with balanced ionization chambers having no moving parts and simplified units with gas-discharge counters. The possibilities of recording the amount of material carried by a conveyor and the amount of a component in a mixture flowing in a tube are considered, as is that of measuring out materials by use of radioactive density meters.

An Integrating attachment to a dredger density meter is described briefly which can be used to measure the amount of solid component (soil) present in the mud during a defined time interval.

Central Research Laboratory "State Mining Technic Control"

USE OF RADIOACTIVE ISOTOPES IN THE TEXTILE INDUSTRY

S. S. Shvyrev, A. N. Slatinsky and K. D. Pismanik

Use of radioactive isotopes in the textile industry has taken the following directions

1. Use of radioactive radiations for automatic measurement and adjustment of weight and weight irregularities in moving textile materials (canvas, tape, coarse linen, yarn and cloth).
2. Use tracer methods for investigating the nature of the various stages of the technical processes of spinning, weaving and finishing.
3. Use of nuclear radiations of high intensity to speed up technical (mainly chemical) processes in finishing.
4. Use of radioactive radiations for removing static charges from textile fibers.

A number of apparatus for weight measurement based on attenuation of rays passing through the material have been developed.

1. RON equipment for measuring and recording irregularities in spun products (tape, coarse linen, yarn). Limits of weight measurement: from 0.3 g/m at cross-section diameters of 15-20 mm to 0.02 g/m at cross-section diameters of 0.2 mm. The unit contains an electronic computer which determines the coefficient of variation.

2. BIV equipment for continuous measurement of weights of materials (bottoms) attached to cloth. The equipment was designed to work with assemblies producing leatherette and oilskins. The two modifications of the unit have measurement limits of 150-800 and 800-5000 g/m².

3. Count regulator for canvas made on the single-process scutching machine. The automatic control unit has to ensure a constant flow of cotton from the reserve chamber to the scutcher.

The regulator is at present on test.

Central Research Institute of the Cotton Industry

EXPERIMENTS ON THE USE OF RADIOACTIVE ISOTOPES FOR THE PRODUCTION MEASUREMENT OF THE WEIGHT OF A MOVING PAPER STRIP WHILE IT IS BEING MADE

E. A. Nekhaevsky

It follows from the basic law of absorption that it is possible to measure the weight/unit area of paper sheet. The chemical composition of the paper is found not to affect the accuracy of measurement. An exception occurs when barium salts are added, this causing a 20% distortion.

Shift of the absorbing in sheet in the measuring gap causes an apparent weight change of up to 15% due to additional ionization in the chamber volume from β -particles reflected from the extra surface of the sheet present within the main solid angle. The weight falls on displacing the sheet towards the source. β -particle reflection within the solid angle then causes a small weight rise. By raising the source area and adding collimator grids, the error due to absorber shift is reduced to 1.5%.

A balancing circuit using ionization chambers is used in the equipment, together with a vibrating-reed electrometer. TI ¹³⁴ was used as the radiation source.

The divisions on the graduated scale were made of constant value by using a nonlinear slide wire in the output circuit and by shaping the mask screening the balance source. The follower system added the readings of the two units using different scale factors: the readings of a needle instrument were used for checking the deviations from the set value and a recording unit for the absolute weight value.

From these investigations an apparatus was designed and put into production which was intended for automatic measurement and recording of the weight of a moving paper strip on a paper-making machine. The measuring head was controlled automatically by a photo-relay and servomechanism so that the head was lifted from the machine when the paper strip broke.

The contactless measurement of weight was shown to be reliable by subsequent weighing of specimens of the paper strip.

The approximate annual saving per machine, due to use of the control equipment and automatic regulator on paper otherwise uncontrolled in weight, was 660,000 rubles.

Goznak All-Union Research Institute

A RADIOMETRIC METHOD OF MEASURING THE HAIR DEPTH IN FUR PELTS

V. A. Pchelina and T. A. Shmeleva

One of the most important indices of fur pelt quality is the state of the hair covering, which indicates its thermal insulation and other useful properties. The decisive signs used in determining the grade of fur pelts are the thickness and uniformity of the hair covering.

The object of this paper was to develop a rapid objective method of estimating the thickness of the hair covering in fur pelts without cutting them.

The studies undertaken led to the development of a unit for estimating the thickness of the hair covering on fur pelts (as mass/unit area). The design of this was based on the measurement of the absorption of Tl^{204} radiation by the hair covering. The unit was termed a radiometric thickness meter.

Use of the radiometric thickness meter in estimating the thickness of the hair covering on fur pelts has a number of advantages over other methods. The unit was of sufficient accuracy to estimate the thickness of the hair covering on any part of the pelt and was simple to operate.

The unit was used under production conditions with different types of fur pelt. The tests showed that a radiometric thickness meter could be widely recommended for use in the practical grading of fur pelts in both dye-finishing and in fur hat production.

Lomonosov State University, Moscow;
Fur Industry Research Institute

USE OF RADIOACTIVE ISOTOPES IN THE LEATHER INDUSTRY

S. M. Smirnov

The results from using radioactive isotopes in the leather industry to check the thickness of raw and cured leather are dealt with.

The experiments showed that the average result of thickness measurements on areas $3 \times 3 \text{ cm}^2$ was approximately that found for a constant density. This made it possible to assume that the mass/unit area, detailed on a sufficiently large area, was a specific parameter of raw leather. The thickness can be estimated from the absorption of radioactive radiation, this depending on the mass/unit area of absorber. The measurement is carried out without direct contact with the material, the size of the measured area being readily selected and adjusted. The experimental data are presented together with estimates of the errors due to moisture, salt content and wooliness.

The possibilities of efficient hide usage from its absorption were studied. The experiments showed that there was a good correlation between the absorption of radioactive radiations and thickness for Moscow leather. In a number of cases the correlation between the absorption of radioactive radiations and thickness was violated with finished leathers, but it would appear from the mass/unit area, as detailed from absorption, that the variability of the deformation due to the mechanical treatment affected the mass/unit area less than the thickness. Hence the mass/unit area is the best index of wear-resistance.

Two radioactive thickness gauges were developed, with their measuring circuits. STS-1 halogen counters were used as detectors, while a Ce^{144} preparation was used as the source. The circuit of one unit was similar to that of an II-3 level gauge. It was made up of a stabilized power supply, a cathode follower (using a 6N9 tube) and an M49 microammeter, $300 \mu \text{ amp}$. The design of the second thickness gauge involved a simplified bridge circuit, in which the balancing source was attached to the moving element of the read-off unit.

Central Research Institute of the Shoe-Leather
Industry

INSTRUMENTS FOR AUTOMATION AND MEASUREMENT USING A NO-CONTACT RADIOACTIVE RELAY

Ya. A. Auzan, V. E. Banashek, Kh. E. Gunne, I. A. Taksar, A. D. Tumulkan
P. F. Chaplinsky, I. A. Eimanis and V. A. Yanushkovsky

Equipment enabling one to perform continuous positive regulation of a measured parameter which does not require quantitative measurement of a radioactive radiation, but is restricted to recording its presence or absence, has become widely used in recent years. Radioactive relays are used in such types of control equipment.

A no-contact radioactive relay using gas-discharge counters is considered. The design principles of sensitive, simple and convenient radioactive relay circuits are expounded.

The circuit of a typical radioactive relay which uses halogen-quenched counters is given.

Detecting, adjusting and signalling units using the radioactive contactless relay are considered; also controllers and a signalling unit working on direct and alternating current, a maximum current relay for the semi-automatic control of transformer parameters, a temperature regulator, a transfer-type liquid-level indicator, a level detector for opaque vessels, and a rotary relay switch for remote-controlled cine projectors.

Institute of Physics, Academy of Sciences,
Latvian SSR

USE OF SHORT-LIVED ISOTOPES IN THE CONTROL OF TECHNICAL STEEL SHEET PRODUCTION

V. V. Kryzhanovsky, I. I. Safyants and V. A. Yanushkovsky

The main principles of using radioactive phosphorus for marking cold-rolled steel sheets are detailed.

Estimates of the activities in the labelling marks of the radioactive electrode and of the total radioactive material introduced into the factory are made in absolute units, and the measures required to prevent accidents in using radioactive marking are considered.

The direction, functions, and tasks of the radioactive laboratory at the TsZL factory are discussed.

The maintenance of general factory standards when using radioactive marking of steel is discussed.

Organization of the marking operation in the cold-rolling mill when radioactive isotopes are used is dealt with.

The technico-economic indices and problems of production programming when radioactive checks are used in factories are analyzed.

Institute of Physics, Academy of Sciences,
Latvian SSR

A TRANSISTOR ELECTRONIC RELAY

V. G. Segalin

The relay is a unit in an automatic apparatus composed of a γ -source and related γ -relay intended for the two-position contactless checking of the course of a technological process.

A transistorized relay has the following important advantages.

a) It is possible to increase the working life of the equipment very considerably even to 70-100 thousand hours:

b) the equipment can be made as interchangeable units, within which any component combination can be sealed hermetically, so that influences due to high humidity, dust, corrosive vapors and liquids, etc., are completely excluded.

In addition, this type of equipment simplifies the production of spark-proof variants considerably.

All-Union Coal Research Institute

LOCATION OF THE LEAK IN A LEAD-COVERED TELEPHONE CABLE

T. V. Abramova

The hermetic sealing of the lead outer casing to the cable is decisive in increasing the reliability of the cable link when this is operated at air pressures in excess of normal.

A method of determining the leakage site in the outer casing using radon or bromine-labelled methyl bromide is described.

The diffusion of these gases in soils of varied composition under various thermal and humidity conditions was investigated. The method ensures that repair and maintenance work on cable sealing is carried out rapidly at all times of the year.

Kiev Division of the Central Communication
Research Institute

LOCATION OF THE GAS LEAKS IN UNDERGROUND GAS PIPES BY RADIOACTIVE ISOTOPE METHODS

V. I. Kuznetsov

Existing methods for the determination of leakage sites in buried gas-pipes are time-consuming, difficult, and ineffective.

A preliminary study of leak location using radioactive $\text{CH}_3\text{Br}^{82}$ was carried out.

The experimental gas-pipes were filled with a $\text{CH}_3\text{Br}^{82}$ /gas mixture.

One pipe was buried in sand, and a second in sand plus clay. The pipes were buried to a depth of 1.7 m. The gas was observed to leak out through tube defects. The activity along the gas-pipe trenches was measured with a monitor.

The site of greatest activity (position of defect) was uniquely identified in the experiments. The effect of the earth on the penetration of the active gas through the sand and clay layers was studied (time required to detect gas leaks-6 minutes).

The results obtained showed that it was possible to use $\text{CH}_3\text{Br}^{82}$ to locate gas leaks, but the activity required (0.3 mC/m^3) is very high and it is thus hazardous in areas when the gas comes out. It is proposed to carry out the work with much lower activities and to determine the effect of soil absorption more accurately.

Institute of Chemical Physics,
Academy of Sciences, USSR

AN IONIZATION METHOD OF γ -RAY FLAW DETECTION

L. K. Tatochenko

The shortcomings of photographic γ -radiography are due to the imperfection of the method of recording the radiation intensity, and so in recent years work directed to replacing the plates by other more refined methods of detection has been carried out in the U.S.S.R. and elsewhere.

A method of γ -radiography in which detectors which transform the γ -radiation into an electrical signal in a linear fashion are used, is termed "ionization γ -radiography" in the U.S.S.R.

Methods of computing the parameters of ionization radiographic setups which differ in purpose, methods for checking castings of great thickness, and methods for checking welds in parts of low thickness are considered in this report.

Simple formulas are derived for determining the optimum time-constant of the integrating stage and the counter input window size, when the ratio of amplitudes of useful signal to fluctuation noise is maximal.

Central Ferrous Metallurgy Research Institute

USE OF SCINTILLATOR COUNTERS IN A BETATRON γ -RAY FLAW DETECTOR

I. G. Fakidov, A. A. Samokhvalov, N. I. Davidenko and
M. D. Avramenko

Studies concerned with the development of a new betatron radiography method are described: this method is used to check thick steel objects (thickness up to 500 mm) continuously at a high speed, the results being recorded on the chart of a recording potentiometer. A betatron of maximum energy 22 Mev was used as the radiation source. Single and differential scintillation counters were used as detectors in conjunction with various phosphors.

The single-counter equipment could readily detect 2-3% changes in a total steel thickness of 300-400 mm at relatively low γ -ray intensities (17 r/min) when the betatron radiation was steady. But the instability of the betatron radiation reduced the sensitivity considerably, since it was difficult to differentiate changes due to flaws from those due to the instability of the betatron radiation on the record. The effect of the instability of the betatron radiation on the functioning of the unit could be eliminated by using a differential scintillation counter. The differential scintillation counter also improved the sensitivity and through-put of the method. The differential scintillation-counter equipment could detect 1% changes of thickness in a total steel thickness of 200 mm, 2% in a total steel thickness of 300-400 mm, and 4% in a total steel thickness of 510 mm.

Preliminary experiments on flaw detection showed that it was practicable to use scintillation counters in a betatron radiographic setup, and that there were prospects of using them in practice to check the quality of thick metallic objects in factories, using betatrons as sources.

Institute of Physics, Urals Branch of the
Academy of Sciences, USSR

METHOD OF RADIOGRAPHING BUTT-WELDS IN TUBES

S. T. Nazarov

It is necessary to check a large number of butt-welded joints in tubes of varying diameter when building reactors and chemical plants. γ -radiography is the most useful of the various methods currently available for detecting macroscopic defects in welded tube joints (particularly when the diameter is small).

A method of checking tube welds using γ -rays was developed, this having a maximum sensitivity to weld defects, together with a special apparatus for the purpose.

By radiography of model joints having artificial flaws, the sensitivities of the γ -images using Co^{60} , Cs^{137} , Eu^{154} and Tm^{170} was established for passage through both walls of tubes of diameters 50, 100 and 150 mm and wall thicknesses of 5 and 10 mm.

The sensitivity of the γ -images with welds in tubes of diameter 50 mm on the side of the weld which was towards the plate was, with Co^{60} , some 5% of the weld thickness; with Cs^{137} 3%; Eu^{154} - Eu^{154} 1.5% and Tm^{170} 0.8%. On raising the diameter, the sensitivity fell (e.g., by 0.5%-1% for welds of diameter 150 mm). The defect detection sensitivity on the side of the weld nearer the source fell by about a factor 5-6.

Hence, to detect the smallest flaws all around the perimeters of welded tubes, two plates had to be taken at a diameter of 50 mm, and three plates at diameters over 100 mm.

Under assembly conditions the joints were usually radiographed with an open source set up with a manual manipulator.

A γ -ray head was developed to improve the shielding and to increase the through-put.

The source could be removed by remote control from the container 4 m away and transferred to the radiographic collimator, placed above the weld under examination in this γ -ray head. The unit reduced the radiation dose to the maximum 0.05

This unit raised the through-put by a factor of 3-4, as compared with the previous one.

Bauman Higher Technical College, Moscow

STUDY OF IMAGE SPREAD ON PASSING Co^{60} γ -RAYS THROUGH STEEL

N. P. Grazhdankina and I. G. Fakidov

Flaw detection using γ -rays is now widely used in industry as being one of the effective methods of checking the quality of products. But further work directed to raising the sensitivity and resolving power is required. The sensitivity is closely connected with the image definition, which determines the blurring of the edges of defects. A knowledge of these factors and of the degree to which they influence the image blurring will assist in efforts at raising the sensitivity of photographic radiography. An experimental study of the effect was carried out, with the object of determining the relation of the blurring to the various factors. The data show that images of defects involve the participation of scattered photons.

The results are used to draw up graphs from which the optimum focal distances for minimum possible image blurring can be detailed. These results can be used in practical γ -ray screening in industry.

Institute of Physics, Urals Branch of the
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USE OF ISOTOPES WITH SOFT RADIATIONS FOR CHECKING WELDS IN SHIP-BUILDING

O. N. Zhukov

X-ray and γ -ray screening methods, using the radioactive cobalt isotopes Co^{60} , which are widely used in shipyards for checking welded joints, have a number of important shortcomings. The bulky nature of x-ray units restricts their use, while when Co^{60} is used in checking small thicknesses (up to 40-50 mm) the sensitivity is inadequate.

Radioactive isotopes with soft radiations (Cs^{137} , Ir^{192} , Se^{75}) can improve the visualization of flaws in welded joints by factors of 1.5-2, i.e., they thus come close to using x-rays. Since it is possible to use high-activity sources without hazard while using only light transport containers (mercury screened), thus reducing the exposure time considerably, wider use of the method in the most inaccessible parts of marine structures is facilitated.

Ir^{192} and Se^{75} can most efficiently be used with angle joints, as well as improving results with welded pipe joints and other important items.

Ir^{192} and Se^{75} can with advantage be used in shipyards, and have replaced Co^{60} almost completely.

Ministry of the Ship-Building Industry

γ -RAY FLAW DETECTOR FOR THIN-WALLED PARTS USING Tm^{170}

S. M. Rummyantsev

The radiographic properties of Tm^{170} are dealt with in this paper. The sensitivity is shown to be 2-4 times greater with Tm^{170} than when Co^{60} , Cs^{137} , Ir^{192} and Eu^{154} are used to examine steel parts of thickness 1-15 mm titanium of thickness 2-30 mm and duralumin of thickness 3-50-60 mm. The effect of various factors on the sensitivity is considered: the weight of the parts, the size and activity of the sources, the focal distance: the flaw position in the metal examined the plate and screen used, etc. Exposure nomograms for use when examining steels, and titanium, aluminum and magnesium alloys were developed and checked under factory conditions with Tm^{170} γ -rays.

The industrial tests with Tm^{170} gave positive results, on which the decision to use Tm^{170} industrially was based.

It was shown that Tm^{170} was of use in checking the following:

- 1) Welded joints and castings, and parts in which flaws had developed during use (corrosion, etc.), made of steel 1-15 mm thick;
- 2) Welded joints and castings made from titanium alloys 2-30 mm thick;
- 3) Welded joints and castings made from aluminum alloys 3-50-60 mm thick;
- 4) Magnesium alloy castings more than 10 mm thick;
- 5) Assemblies, to detect internal faults, derangement of parts, etc.

The guiding principles in using Tm^{170} for radiography and in examining articles (parts) are set out.

A unit for the γ -radiography of metals, using Tm^{170} was also developed.

Research Institute on the Technology and
Organization of Production

USE OF THE SCINTILLATION COUNTER FOR CHECKING THE QUALITY OF PRODUCTS

A. A. Arkhangelsky and G. D. Latyshev

A method for the radiography of metals, using FEU-11 and FEU-12 photomultipliers is proposed, in which the record is taken on a chart recorder.

Experiments on the radiography of butt-welds from plates of varying thickness were carried out by this method, as well as some on parts of complex shape, e.g., railway rails. The method can also be used to detect flaws in light materials, e.g., graphite rods.

The sensitivity is 0.27% at a specimen thickness of 100 mm, with the specimen moving at 10-30 cm/min across the γ -ray beam.

Leningrad Railway Transport Institute

CHECKING WELDED JOINTS BY RADIOGRAPHY AT FERROUS METALLURGY WORKS

L. K. Tatochenko, V. M. Tokmakov and V. K. Latyshev

By using γ -rays for radiography of welded joints it has become possible to organize their examination in many iron and steel works. The use of γ -rays for radiography of welded joints in steel-tapping crucibles, boilers and pipes, in the shells of blast-furnaces and boiler assemblies, in steam-boilers, fire-boxes, oil and gas-pipes have all been reported. Co^{60} was first used as the γ -source, being then replaced by Ir^{192} .

At the same time as photographic radiography was introduced, some work on an ionization flaw-detector was started, this providing very accurate examination of tube welds at diameters of 560-720 mm. This could detect failure to fuse, slag inclusions, blow-holes, and other flaws.

The flaw detector operated by detecting the γ -rays passing through the welded joint. The photo-multiplier/crystal assembly was placed above the welded joint. The radiation source was placed inside the tube, which moved in an axial direction. The source plus detector moved back and forth across the joint line. The detector output was amplified and applied to a pen oscillograph. The record on the chart consisted of separate transverse strokes, which recorded the weld profile, as it were. The presence of a flaw was shown by a sharp kink on the record.

Central Ferrous Metallurgy Research Institute

EXPERIMENTS ON THE INTRODUCTION OF INDUSTRIAL EQUIPMENT FOR THE MEASUREMENT OF THE THICKNESSES OF ROLLED SHEET AND COATINGS

L. N. Baskin, A. M. Bogachev, I. A. Brodsky, B. I. Verkhovsky, A. N. Makarov
N. S. Novoshenya and L. A. Rubinshtein

Units for gauging in cold rolling are at present in use in the undertakings of the U.S.S.R. Ministry of Ferrous Metallurgy, and of some other ministries.

According to the incomplete data on hand the use of units for thickness gauging in cold-rolling has increased product quality, reduced spoilage, reduced the idle time of rolling mills considerably, lightened the work of rolling-mill workers and improved economy in the use of metal. The use of units for measuring tin coating thicknesses in quality control reduced the measuring time considerably and prevented wastage of white tin.

The introduction of units for measuring the thicknesses of hot rollings less than 10 mm thick was accompanied by considerable difficulties, mainly due to lack of soft γ -ray sources.

Industrial use of these units resulted in elimination of various shortcomings, and indicated ways of further refinement. It was also found necessary to solve a number of organizational problems connected with the production of new units and the introduction of existing ones. These were: organization of centralized source preparation and calibration, to satisfy the technical requirements of the various organizations interested; setting up of an organization responsible for hazard control where the units were used; organization of long half-life soft γ -ray source production on the requisite scale.

Central Automation Laboratory, Lebedev Institute
for Oil and Gas Reworking
Molotov Steel-Rolling and Wire-Drawing Works,
Leningrad
Ordzhonikidze "Zaporozhstal" Metal Works

USE OF β -RAY BACK-SCATTERING FOR CHECKING COATING THICKNESSES

B. I. Ermolaev

The lack of information on β -ray back-scattering is an obstacle to wide usage of its valuable features for practical purposes.

The report gives the main data from a study of β -ray back-scattering; this was used to design a unit for coating-thickness gauging on varied materials, which was free from a number of important limitations and shortcomings.

Conditions are disclosed under which one of the main relationships—that of back-scattering intensity to the nature of the scatter—can best be used for coating-thickness gauging.

Results on the relation of back-scattering intensity to the coating thickness are given: from these it is shown that under certain conditions the relation may be practically the same for the majority of coatings and backings, and independent of the shapes, sizes, and cleanliness of the object.

A method of calibrating and constructing the unit which does not demand the use of special thickness standards is given, as well as results from checks of the accuracy of thickness measurements made by this method.

Formulas which define the errors of measurement, the sensitivity, the limits of measurement, and the choice of radiation source are given. The main sources of error and ways of eliminating them are indicated.

A short description of the unit for coating-thickness gauging on β -ray back-scattering is also given, together with its technical characteristics.

EXPERIMENTS ON THE USE OF RADIOACTIVE RADIATIONS IN AUTOMATIC MEASUREMENT AND REGULATION OF TECHNOLOGICAL PROCESSES IN THE MILK INDUSTRY

A. Ya. Vainberg

The problem of all-round automation of continuous processes in the production of dairy products is but one of the present problems connected with developing automatic gauging and control of specific product parameters in a flow system. Contact-free methods are of great value in this connection.

The author's work showed that it was possible to solve this problem in the case of certain specific parameters of dairy products by using radioactive radiations.

The practical solution was to pass the radiation through the product and measure the degree of absorption as being an adequately specific means of determining gauged parameters.

The theoretical assumptions and computed figures were checked by experiment by using U.S.S.R.-produced units (BIV, PZhR, etc.). The relations between the degree of absorption and some specific parameters of dairy products were derived. It was shown that γ -rays could be used for automatic gauging and control of specific product parameters (dry weight of material) in the production of dairy products containing considerable amounts of nonmilk fillers, e.g., sweetened condensed milk. The technical requirements for radiometric apparatus to be used in milk-canning factories are stated.

All-Union Dairy Industry Research Institute

INDUSTRIAL EXPERIMENTS ON CHECKING THE SUCCESSION TRANSMISSION OF PETROLEUM PRODUCTS, USING RADIOACTIVE MATERIALS

B. Z. Votlokhin, A. Z. Dorogochinsky and N. P. Melnikova

Main pipelines have been widely used for successive pumping of varied oil products in recent years. Accurate and instantaneous gauging of the boundaries between the products is extremely necessary at the intermediate and terminal pumping stations. A method was developed in which the interface was labelled with a radioactive material and by recording the activity at the appropriate points on the pipe the boundary could be detected. A certain organic compound—triphenylstibine—was synthesized according to a published method, being subsequently activated by neutron bombardment.

Detecting circuits and recording units for use with the radioactive radiation emitted by the mixture in the pipe were developed.

The unit could be operated by remote control, was of high sensitivity, and gave a record of the radiation detected automatically.

The first tests on sequential pumping using radioactive labels were carried out on a test-bench.

An industrial test of sequential pumping using the main Grozny-Trudo pipeline, of length 886.6 km was carried out in 1956.

At the sending (Grozny) end, the radioactive triphenylstibine, dissolved in 4 ml diesel fuel (activity about 12 mc), was introduced at the interface between diesel oil and kerosene. Observations were made at six pumping stations: Grozny, Pavlodol, Podkumok, Armavir, Rostov and Trudo, test specimens and radiation intensity curves being taken. Laboratory study of the specimens and record gave the following results:

1. The circuits and apparatus seemed completely usable.
2. 4 ml of radioactive triphenylstibine of activity 12 mc was quite sufficient for following the radioactive mixture in the pipe.
3. The way in which the radiation intensity fell off with pipe length was established.
4. The relation between the radiation intensity and the concentration of one oil product in the other was detailed.
5. Use of radioactive triphenylstibine to record the sequential pumping can be recommended if arrangements for centralized synthesis and irradiation of the triphenylstibine are made.

Grozny Oil Research Institute

USE OF RADIOACTIVE RADIATIONS IN RIVER TRANSPORT

S. N. Dedyukov

There are three main ways of using radioactive isotopes and radiations in river transport.

1. Development and wide-spread use of γ -ray soil gauges for suction dredgers. More than 30 such gauges were in operation in 1956, which resulted in the saving of over 2 million rubles, due to increased dredger productivity. A more refined soil gauge with a balanced ionization chamber was designed and tested.

2. Design and manufacture of γ -ray thickness gauges for ships hulls, γ -ray level gauges for checking the water-level in the Moscow navigation canal, and other equipment.

3. Tracer methods for studying the way various factors influence the wear of ships' drives and mechanical equipment, and wear-resistance studies on coatings applied to repair worn parts.

U.S.S.R. River Fleet Ministry

POCKET RADIOMETERS AND DOSIMETERS

G. R. Golbek and A. N. Vyalshin

The pocket radiometer was intended for approximate determination of γ - and hard β -intensities (over 1 Mev) in geological and physical operations.

Recording and intensity determination were carried out by both auditory and visual methods. A telephone earpiece was mounted in the radiometer, which gave loud pops when radiation was recorded.

The detector was an STS-1 or STS-5 halogen-quenched counter.

The counter voltage was taken from a pot-condenser voltage-doubler circuit, which operated from the 200v high-tension battery, giving 400v.

The counter pulses were amplified by a thyatron relaxation circuit built around two MTKh-90 thyatrons, and fed to the earphone.

At high count rates an integrator-type scaling circuit was used, operating on the thyatron circuit current.

The type of pocket radiometer is at present produced as unit type RM-2 by the "Geological Survey" Factory of the U.S.S.R. Ministry of Geology and Mineral Resources.

Pocket "click" unit for γ -ray warning. This is a dosimetric unit for individual use as a pocket detector of radioactive radiations. It is intended for detection of γ -rays and approximate estimation of their intensity over the range of 0.03-2000 daily tolerances.

The unit will record β -rays of energy greater than 0.2 Mev, as well as γ -rays.

Two recording methods are used with the pocket dosimeter.

- a) Audible, loud clicks are emitted by an earpiece when the subject enters a radiation zone.

- b) Visual-light flashes are emitted by a signal lamp, which burns continuously in a high-intensity areas.

The "click" unit is analogous to the pocket radiometer, but there is no voltage doubler, and a small STS-4 dosimeter counter is used as well as the usual STS-5 counter, the former extending the dosimetric range of the unit. The scaling circuit in the "click" unit operates on the charge accumulating in the counter circuit.

The unit has four switched working ranges.

- a) The first range is for survey purposes, using the STS-5. This counter detects radioactive contamination of clothes and objects.

- b) The unit is practically silent giving 1-2 clicks/sec, a continuous buzz being emitted at 100 times tolerance and above.

c) Range 3 is as range 2, the figures being 10 and 100 times tolerance.

d) On range 4 the same effects are observed at 100 and more than 1000 times tolerance.

The power supply for the "click" unit is a replaceable GBM-400, 0.01 battery. If the battery is carefully assembled and sealed with a wax/rosin mixture it lasts for 5-6 months when used daily for 8 hours.

Measuring Equipment Laboratory, U.S.S.R.
Academy of Sciences

EXPERIMENTS ON THE USE OF RUSSIAN GERMANIUM TRANSISTORS IN BUILDING RADIATION MEASURING EQUIPMENT

G. R. Golbek and A. N. Vyalshin

Transistorized pocket radiometer: This is intended for the detection and measurement of β and γ -rays.

Power supply is from a KBS pocket battery or three small FBS cells. The small current drain enables the radiometer to operate continuously from one battery for a long period (30-50 hours).

The radiometer has five parts:

- Radiation detector—an STS-5 halogen counter.
- A highly stabilized and smoothed voltage generator which feeds the halogen counter and output transistor.
- Counter pulse amplifier.
- Output power amplifier plus telephone earpiece;
- Scaling circuit of integration type.

P2B or P6A transistors can be used as amplifiers, but the best results are given by the P6A, including temperature-variation changes. The TKR radiometer, which uses only P6A transistors, works normally over the range from -20°C to $+55^{\circ}\text{C}$. This range is quite sufficient for field work.

γ and β -rays are detected (with β -rays, only at energies above 0.2 Mev).

Detection of radiation causes loud clicks to be emitted by the earpiece. Quantitative results are obtained by counting the number of clicks per unit time.

Wt. 297 g. Dimensions $121 \times 67 \times 26 \text{ mm}^3$.

The unit can be placed easily in the breast-pocket of a coat.

Transistorized field radiometer with integrator circuit. This is intended for field or laboratory measurement of radiations using an electromechanical counter to record the counter pulses, using a Geiger counter and input transistor.

Scales of J, 8, and 64 are used in the unit. Scaling is by binary stages of special type, distinguished by their wide voltage feed acceptance range (3-15v) and their good temperature stability (range -20 to $+50^{\circ}\text{C}$).

The unit records the count rate of randomly distributed pulses with a linearity not less than 10% when count rates of up to 120,000/min are used with the scale of 64.

A special generator is used to provide the power supply to the counter, this giving voltages of 380 or 950, stabilized to 3 v.

The transistor radiometer is built with U.S.S.R. transistors types P1A, P1E, P2B and P3V.

Two pocket KBS batteries are used for the power supply, or else any convenient source giving 4.5-9 v.

The radiometer draws not more than 30 ma when working, and test shows that the pocket batteries cover 30-50 hours of continuous operation.

U.S.S.R. Academy of Medical Sciences

USE OF A DIFFUSION CHAMBER FOR MEASURING LOW ACTIVITIES

V. K. Lyapidevsky

Various methods of inserting the activity under study in the sensitive layer of a diffusion chamber are considered. The best way is to insert the sample via holes cut in the chamber wall near the base. The operation of the chamber is thereby least disturbed. The sample must be kept at the base temperature for some time before inserting it.

There is a general shortcoming in all methods of introducing samples directly into the sensitive layer: vapor condensation on the sample surface restricts the time of measurement and hence the statistical accuracy.

Study of the temperature and partial pressure distributions shows that under some conditions the supersaturation may be less than unity in a large chamber. In particular, when the total chamber height is 100 mm and the sensitive layer is 12 mm thick the zone where the supersaturation is less than unity begins at a level of 30 mm from the base and extends the rest of the way up to the top. The supersaturation is also less than unity near the walls.

When the specimen is placed near the walls or above the condensation zone, the ion track may be displaced into the sensitive layer with focusing electrodes and the particle thus recorded, 2π and 4π geometries are readily produced by placing the sample above the condensation zone.

α - and β -activities in the 10^{-12} C range can easily be measured with high statistical accuracy in this arrangement, since the time to which the measurement is restricted is that for the vapor to condense on the specimen surface, this condensation being inevitable in other methods of mounting, and being eliminated here.

The diffusion chamber can also be used to measure the α and β -activities of gases. The chamber is made higher for this purpose, the volume also being increased thereby, and an electric field which forces the ion tracks into the sensitive volume is applied. α -activities of 10^{-13} e/liter order can be determined in this way.

Moscow Physico-Engineering Institute

THE MEASUREMENT OF WEAK CURRENTS

K. S. Kalugin and V. V. Markelov

This paper deals with the reduction of grid current in tubes used in electrometer circuits. Measurement of the grid current in tubes used in electrometer circuits showed that the most useful circuit is a cathode follower. The tube is then operated in a way quite different from usual. E. g. the 6Zh1Zh tubes used were operated at cathode currents around $5 \cdot 10^{-7}$ amp and at very much reduced heater voltages (1-2v), the cathode load being raised to $10^8 - 10^9$ ohms in order to maintain the cathode output. In this way the grid current in 15 tubes type 6Zh1Zh out of 20 studied could be made not greater than 10^{-18} amp, while for 5 tubes out of the 15 the grid current was $3 \cdot 10^{-18} - 5 \cdot 10^{-18}$ amp.

In this way a number of electrometer circuits were developed which were distinguished by their high current sensitivities ($10^{-18} - 5 \cdot 10^{-18}$ amp) and which were quite stable in use.

The following tube electrometer circuits were proposed:

- 1) A two-stage d.c. amplifier with unbalanced input, using cathode followers;
- 2) A two-stage d.c. amplifier with balanced input, using cathode followers;
- 3) A differential d.c. amplifier with strong negative voltage feed-back;
- 4) A cathode follower circuit for use with a 16ZP electrometer triode, filament heating being by amplitude-stabilized rectangular current pulses.

All the circuits given have been in service for quite long periods, and were extremely stable.

U.S.S.R. Academy of Medical Sciences

OUTFIT FOR WIDE-RANGE MEASUREMENT OF INDIVIDUAL γ -RAY DOSES

L. V. Vorobyeva K. S. Kalugin and Yu. M. Shtukkenberg

The IDK-3 assembly is made up of a set of small ionization chambers and a charge-measuring unit. Each chamber can be used to measure individual X- and γ -ray doses from 0-50 r with a calculated accuracy at the lower end of 0.005 r. The chambers were made of air-equivalent plastic, thus making the readings independent of γ -ray energy over the range from 80 kev to 1.5 Mev.

The doses were determined by the charge collected on the measuring condenser, this being zero in the absence of radiation. Saturation current in the chamber was ensured by an adequately high voltage (300 v) on the charged condenser in a series-parallel capacity circuit, the ionized volume being that of the measuring condenser. Operation of the ionization chamber completely rules out leaks in a chamber not under irradiation. Since the voltage across the measuring condenser was proportional to the dose, the error caused by leak is independent of the dose. In this way dose measurements can be performed with high accuracy over a very wide range with one chamber, and the use of the unit with an automatically switched scale or with a logarithmic scale is facilitated, this being important when the order of the doses to be measured is unknown. Leak in the charged condenser scarcely affects the accuracy of dose measurement, since the chamber capacity is many times less than that of the measuring condenser, and the potential charges on them are inversely proportional to their capacities.

The ionization chambers were cylindrical, of outside diameter 16 mm and length 110-120 mm. The charged and measuring condensers were placed at the ends of a hollow cylinder, the center part being the ionization volume. The charged and measuring condensers were placed in contact with the leads from the measuring panel by flexible membranes, which also served to seal the ionization volume. Special condensers with polytetrafluoroethylene sheet insulators were used in the ionization chambers, these being made to our specifications. These condensers have the following important advantages over the "styroflex" ones previously used:

- a) Much higher insulation resistance (leak per hour not exceeding 0.1-0.2%);
- b) Much less variation in insulation resistance with humidity;
- c) Aging practically absent;
- d) Much less variation in insulation resistance due to irradiation even at very high doses (up to 200 000 r);
- e) After irradiation at very high doses the resistance was quite restored in a relatively short time.

Hence the irradiation of the chambers by the doses measured did not introduce an additional source of error into the measurements from change in the condenser parameters.

These chambers gave readings linearly related to dose over quite a wide dose-rate range (up to 10 r/sec).

The charge-measuring head was designed as a bench unit, and was fed by alternating current. It had three ranges of measurement automatically switched: 0-0.5 r, 0-5 r and 0-50 r.

U.S.S.R. Academy of Medical Sciences

USE OF A PHOTOGRAPHIC PLATE-CRYSTAL SCINTILLATOR SYSTEM FOR RECORDING γ -RAYS

R. M. Kogan and N. K. Pereyaslova

The use of a photographic plate-crystal scintillator system for recording γ -rays is described in the article, an NaI(Tl) crystal and FS-3 plates being used.

It is shown that the sensitivity of such a setup is some $10^3 - 10^4$ times greater than that of a photographic plate used directly.

The measurable range of doses using this system is from $5 \cdot 10^{-4}$ to 50 r.

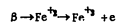
Further ways of refining the system for recording doses or dose-rates from γ -rays are indicated, and the minimum detectable γ -ray dose rate is estimated.

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A PHOTOCOLORIMETRIC METHOD FOR β -RAY ACTIVITIES

M. F. Lantratov, V. E. Manoilov and O. A. Myazdrikov

One indirect method of β -ray dosimetry is based on measurements of concentrations of materials in aqueous solution. It is particularly efficient when the valency of an ion is changed by radiation, e.g.



and when the fresh valency state gives a distinct colored complex (e.g. with rhodinites). The dosimetric formula in photoelectric colorimetry is:

$$D_\beta = \frac{1}{\epsilon \eta C_0} \ln \left(1 - \frac{i}{i_0} \right),$$

where D_β is the β -ray dose;

ϵ is the extinction coefficient of the complex formed;

η is the β -energy utilization factor;

C_0 is the initial concentration of the ion which changes in valency under irradiation;

i_0 is the photocell current corresponding to the light flux before passage through the cuvette;

i is the same, after passage through the cuvette.

It was confirmed by experiment that doses from β -rays and x-rays corresponding to specific activities of 10^{-4} to 10^{-5} c/ml could be measured in a few minutes. This limit can be reduced by 2-3 orders of magnitude.

Lenin Electrotechnical Institute, Leningrad

A GALVANIC METHOD OF MEASUREMENT FOR β -RAY ACTIVITIES

V. E. Manoilov, O. A. Myazdrikov and M. F. Lantratov

The various technical methods of β -ray dosimetry are based on various processes of interaction of electrons with matter. Consideration of these shows that all the possibilities have not yet been tested and described. One method, so far undescribed, used the 'galvanic' principle of measuring doses and dose-rates.

1. A number of ions in compounds are caused to change in valency by irradiation, by β -particles in particular. Examples of such radiation oxidation and reduction are:



Their quantum yields have been computed to be 15.6 and 2.5 ions per 100 ev. Computed back on the basis of 1000 for these are 19 and 3.0 μ moles respectively. The oxidation and reduction processes are the basis of chemical dosimetry. The dose itself is then determined analytically as the yield of product on the right-hand sides of (1), the amounts being about 10^{-4} g.

Estimation of doses from changes in oxidation/reduction (redox) potential represents a step forward, the changes being caused by radiation-induced concentration ratio changes (more accurately, in the $\text{Fe}^{2+}/\text{Fe}^{3+}$ activities). This enables one to make continuous recordings, and what is more, eliminates errors in the final result which are due to secondary processes occurring subsequent to the irradiation.

2. The above data were also used to derive one further principle for measuring β -ray doses, based on measurement of the amount of electricity flowing in a closed circuit due to the potential difference produced.

In this connection the electrical characteristics of a half-cell in the oxidation/reduction system $\text{Fe}^{2+}/\text{Fe}^{3+}$ are of interest when it is coupled to any other electrode, subject to the condition that the $\text{Fe}^{2+}/\text{Fe}^{3+}$ system is continuously subject to the β -rays.

Hence the following electrochemical and radiation processes occur continuously in a closed circuit:



so half-cells of opposed electrochemical and radiation properties may be chosen.

3. The external characteristics of such cells were found by experiment.

The power used by the positive half-cell when a steady potential is maintained in the $\text{Fe}^{2+}/\text{Fe}^{3+}$ system is a fraction of the energy evolved by disintegration, hence

$$I_{Si} = E_i = \eta C_i \bar{E}_\beta \cdot 3.62 \cdot 10^7 \quad (3)$$

Solving the latter expression for I_{Si} we get

$$I_{Si} = \frac{h}{E_i} \cdot 3.62 \cdot 10^7 q C_i \bar{E}_\beta, \quad (4)$$

where $3.62 \cdot 10^7$ is the disintegration constant;

q is the electronic charge, in coulombs;

η is the fraction of disintegration energy used;

C_i is the activity, in mc;

$\bar{E}_\beta$ is the mean β -ray energy;

E_i is the oxidation-reduction potential of the $\text{Fe}^{2+}/\text{Fe}^{3+}$ system.

By analogy, for the short-circuit point A_{K1} we can write

$$I_{K1} = \frac{\eta'}{E_i} \cdot 3.62 \cdot 10^7 q C_i \bar{E}_\beta. \quad (5)$$

(4) and (5) can be rewritten as:

$$\begin{aligned} I_{SI} &= K_1 C_1 \bar{E}_\beta \\ I_{KI} &= K_2 C_2 \bar{E}_\beta \end{aligned} \quad (6)$$

4. A consideration of the possibility of using these results for measuring activities or doses D_β is necessary in deriving some dosimetric formulas

We assume that we are required to measure a dose D_β or the activity of a β -emitting isotope uniformly distributed in a medium at an activity of C_β mc/cm³, the mean energy being $\bar{E}_\beta$.

Then we get the following expression for the dose rate

$$Pd(\beta) = K_3 C_\beta \bar{E}_\beta \quad (7)$$

and since

$$D_\beta = Pd(\beta) t, \quad (8)$$

where t is the dose accumulation time

$$D_\beta = K_4 C_\beta \bar{E}_\beta \quad (9)$$

where

$$K_4 = K_3 t.$$

After substituting (5) in (7) we get

$$Pd(\beta) = \frac{K_5 [E']}{\eta \cdot 3.82 q} \cdot 10^{-7} I_\beta. \quad (10)$$

Finally

$$Pd(\beta) = K_6 \frac{I_\beta}{S K}. \quad (11)$$

5. Thus, doses, dose-rates, and activities can be measured when $\bar{E}_\beta$ is known, by measuring the short-circuit currents in a source, one or both half-cells of which are reversible.

Leningrad Electrotechnical Institute, Leningrad

A COUNTER FOR THE ABSOLUTE COUNTING OF CHARGED PARTICLES

S. A. Baranov and R. M. Polevoi

A method of calibrating equipment used for counting activities is described. A 4 π counter is used for the calibration.

The basic data for a 4 π counter operating in the limited proportional region with a methane flow are given: the plateau lies in the 2500-3000 v range, the plateau slope being < 0.3%/100 volts; the efficiency is 100% for infinitely thin layers; background in a lead shield is 40 c/min; background in a lead shield plus anticoincidence screen 3-5 c/min.

The resolving time of the 4 π counter is $\tau = 1.6 \cdot 10^{-4}$ sec.

Academy of Medical Sciences, USSR

USE OF PLASTIC SCINTILLATORS FOR RECORDING RADIOACTIVE RADIATIONS

N. A. Adrova, M. M. Koton and Yu. N. Panov

The first consideration was given to the use of plastic scintillators in 1951. Solid solutions of anthracene or stilbene in polystyrene were first proposed, and data on efficient phosphors based on 1,1',4,4'-tetraphenylbutadiene, terphenyl and 2,5-diphenyloxazole in polystyrene or polyvinyl-toluene appeared later.

We studied a large number of polymers and copolymers based on styrene derivatives and methacrylate esters and found that polystyrene still remains uniquely practicable and completely suitable out of all the plastic scintillators. Our work showed that the chemical nature and scintillator efficiency of the organic compounds used to activate the polystyrene were related: e.g., in (9,10) disubstituted anthracenes, tetraphenylbutadienes, polyphenyls, substituted oxazolones, oxidiazoles, and substituted indols.

1,4-d[2-(5-phenyloxazolyl)] benzene, quaterphenyl and 9,10-diphenyl anthracene were the most efficient, 1-e compounds with four or more rings in the molecule. These were followed by the tetraphenylbutadienes, terphenyl, and aryl-oxazolones. The aryl-oxazolones were of lower activity.

Methods of preparing efficient plastic phosphors in the form of transparent cylinders of diameter 3-150 mm and weight up to 3 kg were developed, based on terphenyl with added 1,4-d[2-(5-phenyloxazolyl)] -benzene: These were used for recording radioactive radiations.

Institute for High-Polymer Compounds
Academy of Sciences, USSR

III. PROSPECTING AND DEVELOPMENT OF USEFUL MINERALS, OF HEAT TECHNOLOGY AND MECHANICS

THE ACTIVATION ANALYSIS METHOD FOR ROCKS UNDER WELL CONDITIONS

Yu. S. Shimelevich

Theoretical and experimental estimates were produced for the possibilities of using activation methods for studying the rocks intersected by a bore-hole, in particular as regards the detection of oil-bearing and mineralized water-bearing sand beds and of localizing the water - oil interface in drilled wells.

The oil-bearing strata differ from the water-bearing areas by giving lower activation values for sodium and chlorine, and higher aluminum and manganese activities.

The theoretical and experimental estimates made in the laboratory established the kind of relation between the activity and the bed porosity, the content of matrix elements in the beds, and also the depth to which the strata were tested.

Different readings for the activation were obtained under well conditions with oil- and water-bearing strata - the differences being five or six times as great as with other methods (n, γ) and (n, n). The measurements were made on a γ -ray scintillation spectrometer. The method was tested successfully in the Devonian sand beds of the Tulumazinsk formation (20 wells). In particular, different readings were obtained with oil- and water-bearing strata by this method in wells which gave no differences with the other two methods. The more useful results given by activation caused it to be chosen for solving this particular problem in areas with carbonate collectors and in regions where the mineral content of the strata was small (less than 50 g NaCl per liter), the (n, γ) and (n, n) methods giving no effect in these cases. The results from the first recordings were very encouraging. Activation analysis methods with rocks can be used in prospecting for deposits of useful minerals - aluminum, nickel, calcium, iodine, etc.

Petroleum Institute, Academy of Sciences, USSR.

RADIOACTIVE CORE SAMPLING IN COAL FORMATIONS

Yu. P. Bulashevich, A. P. Fisenko, I. N. Senko-Bulatny and E. P. Didenko

Until relatively recently electrical core sampling was the only geophysical method used in bore-holes in soft and hard coal formations.

The electrical parameters of the coals and surrounding rocks are often similar, however; the coal-bearing strata cannot be uniquely identified in the bore-hole under these conditions. Hence the Geological Institute of the Urals Branch, Academy of Sciences, USSR initiated the development of a radioactive logging method for use with the Urals coal formations.

γ - γ logging appeared extremely efficient, the coal beds being distinguished by maximal scattered γ -ray intensities (source Co^{60}).

The γ - γ method was tested in many Urals coal formations - at Bulashevsk, Egorzhinsk, Chelyabinsk, East Urals, Kizilevsk - and was included in the search head used with coal bore-holes. The successful results obtained in the East Urals formation in 1956 are particularly worthy of note; the brown coals have a low resistance, which is the same as that of the clay beds, and electrical logging is of little use.

In order to define the contacts between coal strata and beds over- and underlying them more accurately, as well as to split up strata of complex structure, the resolving power of the γ - γ method had to be raised. For this purpose the intensity difference due to scattered γ -rays at two counters placed at different distances from the source was used.

(n, γ) logging was tested in the Chelyabinsk brown-coal formation. In agreement with theory, a drop in secondary radiation intensity of up to 30% was found opposite coal beds. These anomalies in the (n, γ) method are very small compared with those from the (γ, γ) method, the latter giving more valuable data on the coal beds.

One may suppose that when the (γ, γ) method is further developed it may be possible to determine the ash content of the coals and the rock density in bore-holes.

Geological Institute of the Urals Branch,
Academy of Sciences, USSR.

A RADIOMETRIC METHOD OF OIL PROSPECTING; STATE OF DEVELOPMENT OF THE METHOD AND EXPERIMENTS ON ITS USE

F. A. Alekseev

The radiometric method is one in which oil and gas deposits are detected directly from the surface of the ground. Research devoted to developing a radiometric method of detecting oil has elucidated the main theoretical problems, and the appropriate equipment has been developed in the Petroleum Institute, Academy of Sciences, USSR, since 1953. Although relatively little work has so far been done, many aerial and surface radiometric traces have been taken over known oil and gas-bearing sites in Lower Povolzh, the pre-Caucasus, and West Turkmen, as well as over areas of unknown oil potentiality. The data obtained were so exceptionally interesting and important that the method can be recommended for the direct detection of gas and oil-bearing formations. Further work is certainly required on operating methods and interpretation, in particular a spectroscopic unit of high sensitivity is needed, before it can be recommended for wide-spread use under varied conditions. Many of the gas and oil-bearing formations used can be clearly seen on the radiometric anomaly maps; in all cases the oil-bearing sites show reduced γ -ray intensities. In general, the oil fields are surrounded by strips of raised γ -ray intensity.

When working up and interpreting the material from radiometric surveys it is necessary to take very careful account of the stratigraphy and lithology of the basement and quaternary deposits comprising the area studied, and the local morphology, and to perform any necessary corrections, since the local geology and morphology exert a marked effect on the traces.

The nature of the radiometric anomalies found over oil-bearing formations is the most important and difficult problem in the theory of the method. This question received much attention when the method was being developed. The observed changes in the γ -ray curves over oil-bearing formations are due to changes in the radioactive element (Ra) contents in the uppermost soil layer, not more than 0.2-0.3 cm deep. The reduced content over oil-bearing strata is due to specific geochemical factors accompanying oil-deposit formation.

These factors (presence of hydrocarbons diffusing from the deposits, raised CO_2 content, chloride salinity, etc.) on the whole facilitate migration of radioactive elements and their removal from the soil over oil deposits, thus determining the distribution of radioactivity in oil-bearing regions.

Petroleum Institute, Academy of Sciences, USSR.

USE OF RADIOACTIVE ISOTOPES FOR STUDYING COAL-PROSPECTING BORINGS

S. M. Zhitnikova and E. A. Savinets

The use of electrical methods of investigating coal bore-holes usually enables one to differentiate the coal seams and to determine their thickness and structure, and also to decide on the nature of the overburden.

However, in some brown-coal deposits, and when transition coal types are mixed with anthracites, there is no clear distinction between the electrical properties of the coal and the surrounding rock, so it is impossible to differentiate the coal seams by electrical logging alone. Radioactive logging methods are of major assistance in this case.

γ - γ logging has begun to be widely used in the Geophysical Coal Geology Trust of the USSR Ministry of Coal Industry; this is based on the study of scattered γ -ray intensities produced when the rock is irradiated with γ -rays (e.g., those of Co^{60}) via the bore-hole. Under defined conditions the scattered γ -ray intensity is inversely related to the density of the surrounding rock.

Experimental work carried out in most of the coal formations in the Union has shown that all coal seams give maximal anomalies on the scattered γ -ray curves. The intensity opposite surrounding rock layers is much lower.

Holes in the bore-hole walls give the same effect, which gives rise to some uncertainty in interpreting γ - γ logs. But the experimental work showed that these uncertainties can readily be eliminated by comparing the γ - γ log curves with those from electrical logging and the natural γ -ray activity.

The positive results from these experiments enabled the method to be used in 1957 for solving production difficulties in areas where the geo-electric conditions were very unfavorable.

The γ - γ unit was included in 84 logging unit orders placed by the Geophysical Coal Geology Trust in 1957.

Geophysical Coal Geology Trust

BASIC QUESTIONS OF METHOD IN THE RADIOMETRY OF WELLS AND THE STATE OF THEIR DEVELOPMENT

V. M. Zaporozhets and V. V. Sulin

This report deals with methods of standard radioactive logging and of working up the data which were developed at the All-Union Geophysical Prospecting Methods Research Institute; these are based on calibrating the γ -log equipment in γ -ray dose-rate ($\mu\text{r}/\text{hour}$) and the (n, γ) log equipment in arbitrary units related to the (n, γ) unit readings when immersed in fresh water, and standard dimensions are specified for the (n, γ) probe as well as a method of selecting the recording speed.

The advantages of using γ -ray and neutron scintillation counters over gas-discharge counters for radioactive logs are pointed out, both as regards determination of the lithologic character of the rock and for evaluating their collector properties.

Determinations of rock porosities by comparison of (n, n) logs using nonthermal and fast neutrons are discussed.

Some physical reasons for using a neutron generator with an accelerator tube and betatron are given. The possibilities of principle involved in using the new units to determine the material composition of rocks and the fluids with which they are saturated are considered.

In this connection new methods of radioactive logging are evaluated as being means of accelerating bore hole drilling; namely (γ, n) and electronic logging.

All-Union Geophysical Prospecting Methods Research Institute

THE SEPARATE STUDY OF NEUTRON MODERATION AND ABSORPTION PROCESSES IN ROCKS

A. I. Kholin

The main reason for the unsatisfactory results when attempts are made to estimate rock parameters quantitatively by (n, n) and (n, γ) methods is that the readings given are produced by the combined effect of various neutron absorption and moderation processes in the rocks.

The neutron densities (N) and the prompt γ -ray intensities (I_{py}) recorded in bore-holes depend mainly on the hydrogen and chlorine contents of the rock, the first being an exceptionally effective moderator and the second a very effective neutron absorber.

Experimental work carried out in No. 1 Laboratory of the Gubkin Petroleum Institute, Moscow, has shown that a rise in the content of one of these elements may cause either a rise or a fall in the observed values of N and I_{py} , depending on their relative contents.

When the hydrogen content is high, a rise in the chlorine content causes an increase in the prompt γ -ray intensity, while when the same rock is dry ($K_r \approx 0.5\%$) I_{py} falls when the chlorine content rises.

When the solid content of the rock water is low a rise in rock porosity causes a fall in I_{py} , but when the solid content of the rock water is high collectors of higher porosity are distinguished by higher I_{py} values.

These results show that radiometric methods in which one of the basic neutron interaction processes is studied in isolation must be developed.

An efficient method, in which moderation processes are predominantly operative, is to record nonthermalized neutron spectra.

In order to use neutron absorption (n, n) measurements are to be recommended for unlined wells, using a low-energy neutron source, and γ -ray spectrometric methods for lined wells.

Gubkin Petroleum Institute, Moscow

DETERMINATION OF THE BORON CONTENT OF ROCK SPECIMENS BY NEUTRON ABSORPTION

V. K. Khristianov, G. I. Panov and A. A. Chernova

This paper gives a short description of a method for determining the boron content of rock specimens quantitatively from their neutron absorption.

The main features of the measuring units, the methods of measurement, and the ways of allowing for factors influencing the results are described; the results of field tests and of a comparison between the neutron and chemical methods are given.

The simplicity of the method, the apparatus and the high through-put lead one to consider that it should find an application in prospecting work, and in other fields in which routine analysis for boron is required.

Institute of Geochemistry and Analytical
Chemistry, Academy of Sciences, USSR.

THE PERSPECTIVES FOR USING RADIOACTIVE RADIATIONS IN GEOLOGICAL PROSPECTING
FOR USEFUL MINERALS

G. N. Flerov, F. A. Alekseev and B. G. Erozolimsky

Four problems on which work is in progress at the Petroleum Institute, Academy of Sciences, USSR are dealt with here; prospects of developing neutron methods, related to the design of a bore-hole neutron generator; neutron activation analysis for the elementary analysis of rocks in prospecting for dispersed and rare elements; radiometric methods of detecting oil and gas deposits; and the use of hydrogen isotopes—deuterium and tritium—for studying the dynamics of underground water.

The most immediate prospect of neutron method development in bore-hole work is directly related to the use of equipment containing γ - and neutron scintillation counters.

The use of such equipment enables one to determine the water—oil interface position more efficiently by (n, γ) logging, using spectrometers on the prompt γ -rays and induced activities, and recording the thermal neutrons.

An instance of the successful use of (n, n) logging with epithermal neutrons to determine rock porosities quantitatively under bore-hole conditions is given.

The most important prospect of neutron method development relates to the use of much more powerful neutron sources, in particular to the design of a bore-hole neutron generator. The prospects for rock analysis and bore-hole studies using neutron generators are considered in detail.

The use of neutron activation analysis for the elementary analysis of rocks in prospecting for dispersed and rare elements is considered. Experimental data on the determination of indium in some sphalerites and of vanadium in titanomagnetite and brown iron ore, are given.

Results of work on radiometric methods of detecting oil and gas deposits are given; methods of dealing with the main theoretical problems in the method are considered.

The possibilities of using hydrogen isotopes—tritium and deuterium—for studying the dynamics of underground water are illustrated by data from tests of the method made in mines.

Petroleum Institute, Academy of Sciences, USSR.

EXPERIMENTS ON THE USE OF NUCLEAR METHODS FOR STUDYING SECTIONS IN WATER-BORINGS

V. A. Ryapolova

Most of the water bore-holes drilled by the organs of the Transport Construction Ministry are drilled by rotary methods. The decision to drill these wells is made from electrical data, but this cannot always supply an indubitable answer as to whether there are water-bearing strata at the site, and if so what are their storage properties. The Laboratory of Engineering geology and geophysics at TsNIIIS* has undertaken to elucidate the prospects of using nuclear methods for siting wells. The studies were performed in various hydrogeological locations.

The work on sandy clay sites showed that the relative specific outputs of the horizons could be estimated, as well as the tasks usually dealt with by radioactive methods (lithologic enumeration of the rocks, detection of water-bearing horizons such as sands and sandstones, and their correlation between wells). The specific output of q -water-bearing horizons in sands and sandstones was adequately indicated by the ratio of the inherent γ -ray intensity from that stratum to that from the clay. This ratio was observed to fall as the specific output increased.

On carbonate formations radioactive methods can serve to detect water-bearing horizons and to differentiate pure water-bearing limestones, clay-limestones, and marls. The water-bearing horizons in limestones were indicated by a drop in the natural and neutron-induced γ -activities. With clay-limestones and marls the natural γ -ray intensity was found to be raised.

Work carried out on granites showed that radiometric methods could be used to detect water-bearing horizons. The amplitude deviations of the I_n - γ curve from a line corresponding to the densest rocks can be used as an index of the specific outputs of the water-bearing horizons.

All-Union Transport Construction
Research Institute

USE OF RADIOMETRIC METHODS IN GEOLOGICAL MAPPING

A. F. Kondratenko

The use of radiometric methods in combination with one another and with other geological and geophysical methods ensures that work directed to drawing up geological maps is most efficiently performed.

The Temir-Tuimsk geophysical expedition carried out such operations on the eastern side of Ala-Tau in the areas of the Ulug-Zask Massif and of the river Bereshi in the Syst Zhul mountains.

The emanation method was found to be the most effective of the radiometric methods, this being of the most fundamental.

* TsNIIIS = Central Scientific Research Institute for Construction.

Using β - and γ -records it was mostly possible to chart areas of raised alluvium radioactivity.

Taking into account the high output and economy of radiometric methods, it is considered desirable to use them at all stages of geological mapping.

Siberian Geophysical Trust Ministry of
Geology and Mineral Resources Conservation

RADIOMETRY IN BORINGS AT HIGH TEMPERATURES

G. N. Strotsky

The temperature in some areas of the Grozny oil-field reaches 150° or more.*

Standard radiometric units (NGGK-51, NGGK-55, RARK) cannot be used at such temperatures.

New units developed for high-temperature operation were developed by the Grozny Geophysical Service in collaboration with the Central Geophysics Research Institute, Gubkin Petroleum Institute, Moscow, and the Leningrad Division of the Oil-Well Drilling Equipment Company.

Test results on various units are given.

A unit produced by the Grozny Geophysical Service and the Central Geophysics Research Institute, and also one produced by the Leningrad Division of the Oil-Well Drilling Equipment Company were put on trial and were used successfully in the most important bore-holes.

Gubkin Petroleum Institute, Moscow

THE RESULTS FROM USING RADIOACTIVE ISOTOPES TO STUDY THE WELLS OF THE BASHNEFT (OIL) COMBINE

A. Sh. Galyavich

Research on the state of bore-holes using radioactive isotopes was begun by the Tuimazinsk Bureau of Mining Geophysics in 1953. Up to and including 1956, 136 bore-holes were studied, some holes being studied two or more times. The isotopes Co^{60} , Zn^{65} , Zr^{95} , and Fe^{59} were used.

The radioactive isotopes were used to test the quality of the well cement, to detect flaws in the liner, to determine the height to which the cement had risen around the liner and to detect permeable strata.

Good results were usually obtained by using isotopes. But analysis of the large body of data led the author to conclude that some very important questions of method remained unsolved.

The need for laboratory experiments in elucidating and detailing the adsorptivities of rocks is pointed out. Unless this problem is studied fundamentally it will be impossible to approach the use of isotopes in studying wells scientifically.

It is also necessary to develop a convenient method of gauging water erosion and to produce refined equipment which can determine the width, number, and direction of fissures in the very near future.

Tuimazinsk Bureau of Geophysics

* As in the original translation.

USE OF WELL LOGGING IN THE OIL AND (NATURAL) GAS FORMATIONS OF THE PRE-CARPATHIAN DOWNFOLD

V. A. Shcherbinin

Experiments were made on the use of radiometric methods for studying bore-holes in old formations and test-borings.

Ways of using radiometry for checking up on the gas and water pumping processes in injection wells are given, and the results obtained from these. The high efficiency of radiometric methods for the lithologic and stratigraphic enumeration of layers in deep test borings is illustrated.

A new method of subdividing the menilite series in the inner zone of the pre-Carpathian syncline is proposed, and the results from its use in correlating the layers found in different areas are given.

It is pointed out that (n, n) methods and prompt γ -ray spectrometry should be included in the radiometric heads.

Gubkin Petroleum Institute, Moscow

USE OF NEUTRONS FOR STUDYING GEOLOGICAL STRATA IN WELLS AND THEIR SEALING PROPERTIES, AND FOR THE DETECTION OF GAS - OIL BEDS

F. Ts. Kron and V. P. Odinekov

The No. 1 Laboratory of the Petroleum Institute, Academy of Sciences, USSR began to develop the latest equipment and new methods of neutron well-logging as of 1953: (n, γ) logging using scintillator units (NGK-LS) induced activity, and (n, n) logging. Production test of the methods and units developed was carried out with the close cooperation of the Gubkin Petroleum Institute, Moscow.

Use of neutron methods for well-logging enables one to obtain valuable information on the layer divisions, and to detect porosity differences and reference points for use in comparing well layers.

(n, n) curves reflect the hydrogen content of the media, and hence the rock porosity. There was a very much clearer relation between the porosity and the indications given on the (n, n) curve than is found with other radiometric methods. By detecting epithermal neutrons, and thus eliminating effects on the (n, n) readings due to the chemical composition of the rock, one obtains a method suitable for quantitative porosity determinations.

Use of neutron methods makes it possible to separate oil-bearing and water-bearing rocks, as well as gas- and water-bearing strata in the layers around line well.

Petroleum Institute, Academy of Sciences, USSR.

WELL-LOGGING BY γ -RAY SCATTERING

E. M. Filippov

The use of γ -ray scattering (γ -ray logging) is shown to be usable for determining the densities and porosities of rocks intersected by a bore-hole. The construction of an advanced unit for use with wells, which uses this method, is described. It is shown that rock densities may be determined with accuracies up to $\pm 0.05 \text{ g/cm}^3$ by this method.

The basic laws by which scattered γ -rays interact with rocks are given, these being obtained by experimental and theoretical study.

The possibilities of principle in using betatrons in work on bore-holes are considered.

Moscow Geological Trials Institute

THE EFFECT OF FRESH FILTRATE ZONES IN THE STRATA, DUE TO THE BORING LUBRICANT, ON THE RESULTS FROM THE (n, γ) METHOD

Yu. V. Galuzo

The effect of fresh filtrate zones in the strata, due to the boring lubricant, on the results from the (n, γ) method is considered.

The work was carried out with a vertical model. These experiments gave curves relating the discrimination of the oil and water-bearing strata to the magnitude of the influx zone. In the cases of practical interest - wells filled with water (both lined and unlined) - the differences in the (n, γ) readings vanished completely when the diameter of the zone was greater than 50-75 cm, depending on the design of the equipment. Use of boron screening with the equipment made it possible to differentiate the oil and water-bearing strata when the zone was much larger.

Raising the diameter of the unit without using boron screening caused the observed effects to become smaller. When there is such a zone it must be taken into account when interpreting the results quantitatively. E.g. the porosity should be detailed immediately after the cessation of boring, the penetration zone being then largest, which may possibly also eliminate effects due to dissolved solids in the strata water. The oil saturation should be detailed some time after boring the well; if this is not done, errors due to the zone of penetration may occur.

Gubkin Petroleum Institute, Moscow

THE EFFECTIVE RADIUS STUDIED IN RADIOMETRIC OIL-WELL LOGGING

A. V. Zolotov

The slow neutron and secondary γ -ray density distributions over the whole volume of a stratum must be studied in order to determine the profundity of radiometric methods; the γ -ray scattering and absorption processes in the rock when the conditions are those of an unbounded uniform medium, and those of wells, must also be studied.

All these problems were studied on an artificial model (height 5m, diameter 2.3 m) these dimensions being known to give negligible end-effects.

When the profundity of γ -ray and isotopic methods was studied it was found that the effective absorption coefficients for γ -rays in a natural sandstone were in good agreement with the linear sums of the γ -ray absorptions in aluminum without allowance for the Compton effect. In this way a graph relating penetration depth to γ -ray energy was drawn up.

The experimental work on the model and theoretical calculations gave curves showing the relation between effective radius of action for neutron methods and rock hydrogen content. Analysis of these curves gave the important result that, with oil sand deposits of useful width, when the porosity changed over the range of practical importance (15-25%), the radius of action of the NGM (n, γ) method changed only slightly.

The work on the action zone of radiometric methods in well conditions, and that on the relation of the zone width to the probe length, are not yet completed and are not dealt with in the report.

Volga-Urals Branch of the All-Union Geophysics Research Institute

STUDY OF SUBTERRANEAN HYDRODYNAMICS USING RADIOACTIVE ISOTOPES

V. A. Filonov, Ya. B. Finkelshtein, V. N. Soifer and M. P. Obukhova

The tracer liquid used was tritiated water inserted via a pressure-water bore-hole and determined in water from wells in use.

An electrolytic apparatus for tritium enrichment of water is dealt with; the maximum possible enrichment was by 3-4 orders of magnitude. The sensitivity of measurement under industrial conditions was $5 \cdot 10^{-7}$ curie/ml.

It is stated that the main contribution to dilution of the labeled-water volume is due to self-diffusion in the flow, and the role of diffusion in bound water is slight.

The use of tritium for studying the water-pressure regime at the October field in the Grozny area is considered.

OIL Institute, Academy of Sciences, USSR.

USE OF RADIOACTIVE ISOTOPES IN THE OIL INDUSTRY

A. A. Korzhev

The use of radioactive isotopes as radiation sources for solving a variety of problems in industrial geology and geophysics is, to a considerable extent, defined by the capacity of the rocks to adsorb radioactive substances.

Research on the adsorption of radioactive isotopes in various rocks, in particular clays, sands and other materials, has shown that iron ions adsorb least, as compared with those of cobalt, zinc, zirconium and cesium. Cesium ions are adsorbed to the greatest degree. Radioactive ions of iodine, ^{131}I -labeled, are practically not adsorbed on sand and clays, and so this isotope is most useful for work on the storage properties of permeable strata.

Research on the adsorption of radioactive isotopes in the presence of aqueous solutions of salts and acids showed that the adsorption mechanisms for radioactive isotopes may be controlled by changing the chemical composition of the solution filtering through.

Activated sand was used in some of the work on wells, as well as solutions of radioactive isotopes as γ -ray sources. The technique of activating sand is as follows: a layer of a salt containing a radioactive isotope, some tens of microns thick, is deposited on the surface of a sandstone. This layer is then fixed by heat-treatment or coating with lacquer. This sand is then used to check the hydraulic destruction zone in the stratum.

There are also some other problems in the prospecting and production geology of the Oil industry which can be solved by the use of radioactive isotopes. Such are: delineation of permeable strata, checking the mobility of water by contour delineation, detection of oil-bearing strata in geological bore-holes, checking perforation quality, checking the usage regime of a productive stratum, etc.

All-Union Geophysical Prospecting Methods
Research Institute

QUANTITATIVE INTERPRETATION OF RADIOMETRIC WELL-LOGGING

Yu. A. Gulín

A short review of existing radioactive well-logging methods and their development prospects is given in this report.

The (γ, γ) method was used to estimate rock densities. The author's work on the oil-deposits of Bashkiria with this method showed that a unit of special design had to be used to get quantitative results, this design reducing effects due to bore-hole diameter changes and changes in the boring-fluid density.

Neutron-logs were used to estimate the chlorine and hydrogen contents of rocks.

Since the secondary γ -ray intensity and slow neutron density are determined by both the hydrogen and chlorine contents, if one of these parameters is to be studied in isolation, the effect of the other must be reduced to the maximum possible extent. When the hydrogen content of strata containing mineralized water is studied, this is done by using an assembly of (n, γ) probes in the same head but differently disposed with respect to the irradiated stratum and well in each case.

Great possibilities for hydrogen-content determination were found by using recordings of epithermal neutron densities, these being dependent on the chlorine content of the rock to only a very slight degree.

To estimate the chlorine content of a stratum, the author recommends the combination of (n, n) and (n, γ) methods, the best results being obtained by using (n, γ) probes which are short $l = 20-25$ cm.

All-Union Geophysical Prospecting Methods
Research Institute

USE OF RADIOACTIVE ISOTOPES FOR STUDYING BLASTING IN MINING

G. I. Pokrovsky and A. A. Chernigovsky

The removal of soil during blasting has so far not been studied theoretically. In particular, there is no formula from which one can determine the thickness of the deposit at a given distance from the explosion center,

Starting from the fact that a cone-like jet is formed in blasting, the following formula for the deposit thickness S at a given distance x is readily derived:

$$S = \frac{1}{3} W^3 \frac{\sin \varphi}{x \cos^2 \varphi} \cdot \frac{d\varphi}{dx},$$

where W is the depth at which the charge is placed;

φ is the angle of ejection;

$\frac{d\varphi}{dx}$ is the derivative of the throw-out function $\varphi = F(x)$.

Radioactive isotopes were used to find the unknown function $\varphi = F(x)$. A small volume of soil present in the ejection cone was labeled with P^{210} . The surface was surveyed with a sensitive monitor after the explosion to detect the labeled earth. From measurements of the ejection angle and the flight distance x a set of graphs of the function for various indices of explosive action was drawn up. The layer thickness computed from this formula using the experimentally found function was in good agreement with that found by experiment. The experimental function can be used with any charges.

The use made of radioactive isotopes in this work gives one cause to assert that their use is highly effective when the most complex processes occurring on firing charges in soils and rocks are investigated.

Zhukov Air Force Engineering Academy

USE OF RADIOACTIVE ISOTOPES IN THE DRESSING OF COALS AND IN CHECKING THEIR QUALITY

V. D. Goroshko

A program of various research projects related to the use of radioactive isotopes and radiations has been carried on for several years at the Academy of Sciences, USSR Fuel Resources Institute, one of these projects being the study of γ -rays as a means of checking the content of impurity minerals in enriched coal products, and also in the primary purification of coal via the automatic rejection of rock. Both projects are based on the relation of γ -ray absorption to coal density and composition. Theoretical work shows that the main compounds entering into the composition of coal and its mineral impurities have γ -ray mass-absorption coefficients for the 0.3-1.0 Mev energy range which are practically dependent on the energy alone and independent of the absorber composition. When the γ -ray energy is further reduced, the over-all sum of the absorption coefficients for the coal-mineral impurity mixture, as computed by the addition of the mass absorption coefficients for the elementary constituents, begins to depend on the chemical composition of the mixture.

This must be allowed for when choosing γ -rays for checking coal-enrichment products and for separating coal and rock lumps.

We carried out experiments on the absorption of γ -rays in coal pyrites and coal-rock briquettes, as well as on lumps of coal and class Co^{60} , Cs^{137} and Se^{75} coal from the Novo-Kondratyev enricher. The briquettes were used to get reproducible experiments under identical conditions.

STS-1 halogen counters were used as detectors, as well as scintillation counters (sodium iodide crystal plus EU-19 photomultiplier). A standard type B unit and a measuring ratemeter type ISS were used for measurement.

The original theoretical concepts were confirmed by the experimental work— ^{56}Fe appeared to be the most useful of the radioactive isotopes used, this having soft γ -rays. Calculation shows that the use of isotopes with even softer γ -rays, such as Tm^{170} , Ni^{59} , Fe^{55} , and Ra-D , must be even more effective.

A working model of a radiometric separator for separating coal and rock lumps of size up to 100 mm was designed and built at the Fuel Resources Institute. In the separator the coal and rock lumps were automatically directed to a number of pockets, into which they fell one by one; the moving lumps passed through a radiation beam, and were directed into one of two receivers by a special unit, depending on the degree of γ -ray absorption. Scintillation counters were used as detectors. Halogen counters, which have some advantages, can also be used. At present, various studies on the conditions for separating coal and rock are in progress on separator models, and various radiators, detectors and radiometric equipment are on test. The USSR Coal Industry Ministry (Hydro-Coal enrichment Institute) has developed an experimental industrial radiometric separator based on our model.

An express method for checking the mineral impurity content in coal-enrichment products was developed, this using a Geiger-Muller counter together with a standard F unit. γ -ray absorption measurements were made in an aqueous medium containing a wetting agent, in a cuvette.

Work on the choice of a γ -ray source is at present in progress, as well as work on the errors and conditions of measurement. There is no great difficulty of principle in passing from express-analysis to automatic continuous checking, particularly as regards the measuring side. The most difficult problem is to ensure a uniform and continuous passage of a representative fraction of the general flow of coal or enriched product.

Academy of Sciences, USSR, Fuel
Resources Institute

THE THEORY OF NEUTRON-LOGGING IN WELLS

S. A. Kantor and A. Ya. Temkin

The neutron distribution in a cylindrical model stratum, which does not contain hydrogen, is computed. The minimum permissible model diameter, at which edge effects can still be neglected, is estimated, and it is assumed that the distribution of neutrons emitted from a point source on the model axis coincides with that in a uniform infinite stratum.

To facilitate solution of the boundary conditions in neutron moderation theory a method analogous to the image method used in electrostatics is proposed. The solution of the kinetic equations for the neutrons obtained by this method can be checked if its Green function can be derived for a uniform medium of infinite extent. An example is given of the solution of the one-dimensional kinetic equation when there is a single flat boundary between two distinct media.

The spherical harmonic method, as applied to solve the kinetic equation, can be improved on by expanding the distribution function as a series of eigenfunctions of the differential operator which enters into the equation, and dividing the equations obtained by the eigenvalue of this operator.

A method of solving the kinetic equation for the passage of neutrons through a moderator with a low hydrogen content is developed; this simplifies the calculation of the neutron distribution considerably in this case. The method was applied to solve some problems in neutron logging in the Tatar and Bashkir regions, where the oil-bearing sandstone porosities are about 20%.

All-Union Research Institute for Geophysical
Prospecting Methods

ESTIMATION OF THE POROSITY AND OIL-SATURATION OF SANDY CLAYS BY THE (n, γ) METHOD FROM THEIR CHLORINE CONTENTS

V. V. Larionov

Curves of the relation $I_{n\gamma} = f(K_p)$ between the relative prompt γ -ray intensity $I_{n\gamma}$ and the porosity coefficient K_p of the water and oil-bearing sandstones were obtained for the Tuimazinsk devonian deposits and the Lukhanovsk carboniferous strata.

With reliable wells examined some time after being bored, the rise in sandstone porosity was accompanied by a marked rise in the relative magnitude of $I_{n\gamma}$, the form of the $I_{n\gamma} = f(K_p)$ curve being close to linear.

The general shapes of the $I_{n\gamma} = f(K_p)$ curves for oil-bearing sandstones were as for the water-bearing ones. There was a general reduction in the magnitude of $I_{n\gamma}$ and in the slopes of the $I_p = f(K_p)$ curves, however.

There was no correlation between the (n, γ) log readings and the porosity in unlined wells. Only a general tendency of the readings to increase with the porosity was found.

Two graphs of the relation between the relative $I_{n\gamma}$ and the water-saturation coefficient K_w were drawn up for the devonian sandstones of the Tuimazinsk deposits, for high ($K_p > 18\%$) and low ($K_p < 14\%$) porosity. As the water saturation rose $I_{n\gamma}$ increased in both cases, but with low-porosity rocks the rise was slight, falling within the limits of error of measurement.

For rocks of high porosity ($K_p > 18\%$) changes in the oil-saturation from 0 to 100% corresponded to changes in $I_{n\gamma}$ from 1.44 to 1.22, the $I_{n\gamma} = f(K_w)$ curves being approximately linear.

Institute of Fuel Resources, Academy of
Sciences, USSR.

A RADIOMETRIC METHOD IN STUDIES OF THE MECHANISM OF COAL-DRESSING (STUDY OF THE IMPEDED FALL OF BODIES IN A LIQUID)

V. D. Goroshko

In gravitational coal-enrichment processes the coal and rock lumps are separated under conditions of so-called hindered motion, where the lumps experience not only hydrodynamic resistance from the medium, but also resistance due to impact and friction upon collision with one another. The problem of the motion of a solid body en masse with similar or different solid bodies goes beyond the limits of gravitational enrichment, since it occurs in branches of Technology where systems of solid bodies suspended or driven in a liquid or gas are involved (hydraulic and pneumatic transport, gas purification, water technology, etc.).

Although a number of valuable studies have been made both in the USSR and elsewhere, the theory of the gravitational process is divorced from its practical use in coal enrichment on account of the difficulties in deriving the laws of hindered motion of bodies.

A radiometric method using γ -rays, has been used at the Institute of Fuel Resources of the USSR Academy of Sciences to study the laws of hindered fall for bodies in a liquid. In this method one or several solid particles were labeled with a radioactive isotope which emits γ -rays of energy and intensity sufficient to pass through the suspension and be detected by a special unit.

Irradiation in a nuclear reactor and galvanic coating with Zn^{65} were used to label metal particles. Coal particles were labeled by depositing an insoluble salt labeled with Co^{60} within and upon them. The coating

was attached by a thin layer of bakelite lacquer.

Two methods were used to record the passage of labeled particles through two apertures in the vertical tube in which the hindered fall of similar particles took place: one using Geiger-Muller counters, connected in pairs in a coincidence circuit, one at each level, and the other using scintillation counters, one at each level. The measuring circuits were built up from the type B units widely used. A pen oscillograph was the recording unit in both cases. The scintillation-counter circuit was the simpler and more sensitive of the two, but the movements of the labeled particles were detected over a somewhat greater solid angle.

In order to raise the sensitivity in the Geiger-Muller coincidence arrangement additional lead shielding was added.

Using these arrangements, work on the hindered fall of bodies in pure liquids and in suspensions was carried out, as well as work on the viscosities of suspensions.

Institute of Fuel Resources of the
Academy of Sciences, USSR.

A RADIOMETRIC OIL AND GAS WELL LOGGING EQUIPMENT

V. M. Zaporozhets and Ya. Ya. Gorsky

Since 1953 the "Oil Equipment" Factory has produced an NGGK type radiometric apparatus, which was developed by the Gubkin Oil Institute, Moscow, for use with wells drilled by rotary boring, and includes both (n, γ) and γ -logging units. Nine type VS-9 gas-discharge counters are used as γ -ray detectors, thus enabling the rate of movement of the head to be raised to 300-400 m/hour. As of 1954, the factory has produced a selected RARK unit suitable for use with "Krellius" wells. It has been possible to produce these types of equipment because radiometric methods have been widely introduced into the oil industry.

Recently the factory has developed new types of radiometric units in collaboration with other organizations.

1. A unit which is temperature-stable, comprising single-channel and two-channel probes of types STP-RK-56 and STP-NGGK-56 with which measurements can be made in deep wells at temperatures up to $+150^\circ$ and pressures up to 700 atm.
2. A portable unit, type SP-48, of diameter 48 mm intended for use with seismic and "Krellius" wells.
3. A unit type NGK-2VNK-56 for detecting water-oil interfaces by the (n, γ) method and for carrying out (n, γ) logs.
4. A well cementometer type STs-2-4, intended for detecting eccentricity of well linings in the well.
5. A two-channel unit, with scintillation counters, type NGGK-LS-51, intended for simultaneous γ and (n, γ) logs in wells.

The γ -ray detectors in the equipment are scintillation counters, made up of FEU-19M photomultipliers and CsI (Te) crystals, thus raising the rate of scan considerably and improving the detailed discrimination of geological strata.

The supply to the photomultiplier is from a high-voltage generator having a highly stable output (up to 0.1%). The complete equipment included single-channel and two-channel depth probes, the surface panel and its attachments.

Since special phosphors sensitive to fast or slow neutrons can be used for (n, n) well logging,

6. A column lining coupler was developed to give more accurate depth measurement.

In addition to the types of equipment enumerated above, a multi-channel unit for detailed well study, which uses a single-core cable, was developed.

This work led us to produce light bore-hole (particle) accelerators, by using which, great possibilities of refining radiometric methods are opened up.

All-Union Geophysical Prospecting Methods
Research Institute

ANALOG STUDIES OF NEUTRON DISTRIBUTIONS IN OIL AND WATER-BEARING STRATA INTERSECTED BY A WELL

O. A. Barsukov

The density distributions of thermal neutrons, N_T , and indium resonance neutrons, N_I , were studied on model strata. The conditions simulated were of a well intersecting oil and water-bearing strata.

The axial section and radial densities of neutrons of these energies were investigated.

It was shown that the presence of a well caused deformation of the lines of equal neutron density, these being more closely spaced in the well as compared with the lines in the strata.

A sharp difference between water and oil-bearing strata was observed when the thermal neutron densities were recorded with probes of dimensions between 25 and 60 cm. There was practically no difference between oil and water when indium resonance neutrons were recorded.

Work on the effect of well diameter showed that the nature of the $N = \phi(d)$ relation (d being the well diameter) was very different with the various sizes of probe. E.g., when the probe had $l = 30$ cm the relation was not well defined, while when $l = 60$ cm, N fell as d increased, in accordance with an approximately exponential law.

The water-oil difference was determined in wells of varied diameter and construction. It was shown that when the wells were lined and filled with water, an overwhelming fraction of the neutron flux was moderated in a distance of 10-20 cm from the source, while in porous sandstones this occurred at distances not greater than 30-45 cm.

The increased effect on increasing the probe size from 10-20 cm up to 30-50 cm is explained by the increased relative effect from neutrons migrating into the well from the strata. The lower the rock hydrogen content, and hence the greater the mean path required for complete neutron moderation, the greater the distance from the source where the effect was maximal.

The neutron spectrum was found to become shifted to the higher energy side as the probe size increased, the equilibrium state of the spectrum being characterized by predominance of the hard component. Hence the reduced discrimination between oil and water found when $l < 60$ cm, may evidently be explained by increased energy of the neutrons coming from the strata, the energy of these being so highly epithermal that the effect of absorption by impurities is not great. With the smaller probe dimensions the mean energy of the epithermal neutrons emerging from the strata and falling on the detector is considerably lower, which also means that the absorption by impurities has a much more marked effect.

Gubkin Oil Institute, Moscow

THE POSSIBLE USE OF SCINTILLATION COUNTERS FOR WELL-LOGGING AT HIGH TEMPERATURES

V. N. Mikhailovsky and Yu. I. Sitnitsky

The requirements of a thermostatic unit for operating with scintillation counters at well temperatures of 100-150° are evaluated.

The various possible ways of carrying out thermostating are analyzed (cooling by absorption and compression, evaporation of water under reduced pressure, periodic cooling with ice charges).

The method at present available in practice is shown to be ice cooling. The appropriate calculations and experimental data are given.

The prospects of using thermoelectric cooling principles using a semiconductor battery are considered.

Institute of Machine Operation and Automation,
Academy of Sciences, Ukrainian, USSR.

DESIGN FOR A TELEMETRIC UNIT FOR COMPLEX RADIOMETRIC WELL-LOGGING

V. N. Mikhailovsky and A. N. Svenson

A four-channel telerecording system has been designed to transmit the output pulses from four scintillation counters to the ground surface, the information parameters being not merely the mean pulse repetition frequency, but also their amplitude distribution. The distinguishing features of the system are the use of units for reducing the spectral spread of signals fed to a connecting cable. This unit is made up of memory cells which are charged by the pulses which are distributed according to a Poisson law, and which are discharged uniformly by a commutator common to all channels. Thus the nonuniform pulse distribution is transformed to a discrete one the resolving time of the transmitter being that of the transformer-commutator.

The telerecording unit included a self-adjusting system which practically eliminates effects on the error of measurement due to possible changes in channel parameters. The telerecording system is completed by a computer unit which transforms part of the information received to a form more convenient for geophysical investigation.

Institute of Machine Operation and Automation,
Academy of Sciences, Ukrainian, USSR.

A FIELD RADIOMETRIC UNIT USED IN PROSPECTING FOR OIL FORMATIONS

A. P. Grumbkov

A short description of a radiometric method of oil prospecting, and of a radiometric unit for this purpose are given.

In its general form the radiometric method of oil prospecting consists in producing a ground γ -trace with special equipment, i.e., radiometers; the areas where the γ -ray intensity drops are frequently areas where oil lies.

Industrial automobile and airplane γ -radiometers are of insufficient sensitivity for use in prospecting for oil. Hence the radiometric prospecting laboratory in the Oil Institute doubled the number of counters used; the time-constant of the integrating circuit was also raised. These measures were insufficient in some cases, however. In addition one frequently needs to know which elements are responsible for the radiations recorded.

An automobile γ -ray spectrometer was developed at the Institute, which was based on the coincidence counts in an extended system of electronic counters.

Some results obtained with the γ -spectrometer over an oil deposit are given.

Oil Institute, Academy of Sciences, USSR.

DEVELOPMENT OF A CONTINUOUS-ACTION SPECTROMETER FOR THE γ -RAY SPECTROSCOPY OF WELLS

E. I. Prokofyev and A. P. Tsitovich

Efficient use of prompt γ -ray spectrometry in solving various problems in oil geology can only be made by using highly sensitive differential γ -ray spectrometers.

Pulse-height analyzers using cathode-ray tubes are the most promising in this respect.

A laboratory model of such an analyzer, developed at the Gubkin Oil Institute, Moscow, is described in this report.

The principal features of the unit are:

Pulse amplitude resolution $\pm 5\%$;

Minimum mean count rate 100 impulses/sec;

Resolving time 10 μ sec;

Production models for use in wells were developed from the laboratory specimen.

Gubkin Oil Institute, Moscow

A NEW RADIATION WELL-LOGGING EQUIPMENT USING NEUTRON, PROPORTIONAL AND SCINTILLATION COUNTERS.

D. F. Bespalov.

By using scintillation counters in well-logging equipment, new aspects of radiation methods of oil-well logging were opened up. The effect of local temperature on the stability of operation of the scintillation counter restricted its use very much, however.

The design and construction of scintillation-counter equipment is considered, particularly as regards automatic adjustment of the gain by negative feedback of a reference signal. Apparatus of this type can operate in wells at temperatures up to 90°C.

Oil Institute, Academy of Sciences, USSR.

MEASUREMENT OF THE STEAM VOID SPACE IN STEAM GENERATORS WITH γ -RAYS

Z. L. Miropolsky and R. I. Shneerova

In this report a method of studying two-phase systems based on the use of γ -emitting radioactive isotopes is proposed.

Two methods of determining the true vapor-phase volume are considered: 1) passage of a narrow γ -ray beam through the medium (this makes it possible to derive a diagram of the phase distribution in the object, as well as giving the average vapor volume in the area irradiated); 2) passage of a wide γ -ray beam, this covering the whole area of the object. The influence of the structure in the two-phase flow and the geometry of the object on the absorption of a wide γ -ray beam is dealt with.

Estimates of the possible errors that may occur when the flow structure is unknown are given, and the optimum conditions for using this method are elucidated as functions of the absorption properties and geometrical dimensions of the object.

Experiments are described which confirm that this is a possible method for studying the flow of a liquid-vapor mixture in the steam-generating parts of a boiler.

Khrushchansky Power Institute,
Academy of Sciences, USSR.

USE OF γ -RAYS FOR STUDYING BUBBLING PROCESSES

G. G. Berezolomel, Ya. G. Vinokur, V. A. Kolokoltsev
and V. E. Petukhov

Passage of γ -rays was used for studying the distributions of liquid and vapor (gas) phases in a boiling volume by the Boiler Laboratory of the Power Institute in 1952. By using this method for studying the hydrodynamics of a two-phase fluid the vapor (gas) content of the medium could be estimated from the absorption. The use of γ -rays to study boiling processes was applied to separation columns under various boiling conditions at the Power Institute.

Data were obtained from the experiments which served to explain the liquid and vapor (gas) phase distributions throughout the volume at various plate evaporator loadings, varied pressures and boiler water contents and different pierced sheet immersions. The use of γ -rays was extremely advantageous, and in a comparatively short time data were obtained which gave a much more complete description of the bubble process than those earlier available.

A particularly important advantage of γ -ray methods over others is that it is possible to derive the volume-vapor content throughout the boiling volume and in zones where ϕ changes.

Khrushchansky Power Institute,
Academy of Sciences, USSR.

USE OF A GAMMA-SCOPE FOR STUDYING THE HYDRODYNAMIC REGIME IN A LIQUID-LIQUID SYSTEM

S. S. Kutateladze and V. N. Moskvicheva

A special unit for studying the passage of fluids through a liquid was produced; this could be used to study the density of a two-phase layer of considerable thickness. The unit had a remotely controlled carriage for source and detector. Since an oscillograph and a tensimetric flowmeter were included in the measuring circuits density fluctuations in the beam could be studied. Sources of 5 to 10 mc strength were required for water-steam mixtures; when the time-averaged characteristics of a mercury-water system were required sources of 200 to 500 mc were needed; for studying density fluctuations in such a system, a source of around 10,000 mc is needed.

Similar work was carried out on mercury-water and carbon tetrachloride-water systems. The hole size of the light component inlet ranged from 0.3 to 12 mm, the effective area of the distributor being varied from 2 to 75%. The volume content of the light phase, ϕ , was determined from the absorption, and also from a water pressure gauge, the two not always giving the same result. This is evidently due to kinetic energy losses in the mixing layer. The experiments showed that there was an ill-defined relation between ϕ and the light component feed velocity W_0^* . The fine structure in the heavy component, which occurs after the scouring layer, is stable at W_0^* values less than the critical.

It was found that the mechanisms of the structure crises in the dynamics of a two-component layer had much in common with the crises in the mechanism of boiling at a solid surface. In both cases a critical regime arises, which is to a decisive extent defined by the magnitude of $W_0^* \sqrt{g \sigma (\gamma' - \gamma)}$.

Polzunov Central Turbine Boiler Institute

METHODS FOR DETERMINING THE DENSITY AND MOISTURE-CONTENT OF SOILS USING RADIOACTIVE RADIATIONS

N. A. Tsytovitch, V. I. Ferronsky and V. A. Lukin

Methods of determining soil densities under field conditions are considered in this report: these are based on passing γ -rays through a layer of soil and using the laws of γ -ray scattering for soils of different densities. Two apparatus using these principles were developed; a radioactive yoke and a probe used to gauge the packed density of building foundations. A field pulse recorder, battery-fed, based on a neon-tube circuit after L. N. Korblov, was used to detect the γ -rays.

Results given are from laboratory experiments designed to discover the factors which cause the changes in γ -ray mass-absorption coefficients of soils. The experiments were carried out with a specially built laboratory apparatus in which the γ -ray beams to be detected could be collimated.

The initial experiments on using neutron methods for determining soil moisture under field conditions are also dealt with; the deformation of soils under load in the two-dimensional case was studied in an experimental trough.

The methods of determining soil moisture and density under field conditions are proposed for use in studying soil compression under building loads and in aeration zones, and the changes in ground-water level when creep effects are studied at sites of creep.

Preliminary experiments on the use of radioactive isotopes for solving problems of soil mechanics and engineering geology have shown good prospects.

Kuibyshev Building Construction Institute

DIRECT STUDY OF WATER TRANSFER PROCESSES IN BUILDING MATERIALS WITH A GAMMA-SCOPE

L. G. Polozova and R. P. Reizman

This report deals with the equipment operating principles and measuring methods for use with moisture determinations on building materials by methods involving the passage of γ -rays from radioactive isotopes. This method uses the fact that γ -rays are absorbed to an extent depending on the density and thickness of the materials. The requisite accuracy can be obtained by using narrow γ -ray beams and by adequately screening the γ -counter from scattered radiation.

To determine moisture in building materials by γ -ray methods it is assumed that the absorption of a narrow γ -ray beam by a moist material is the sum of the absorptions that would be found on passing it in succession through the dry material and a water layer of the thickness equivalent to the water content of the material. That this assumption is correct to an accuracy sufficient for practical purposes was confirmed by experiment. When the cellular concretes were examined with γ -rays and dried, the discrepancy in the water content did not exceed 2% of the water weight.

This method enables one to determine the moistness of materials and the transfer of water in materials continuously without destroying the structure of the specimen.

Institute of Building and Building Materials,
Academy of Sciences, Estonian SSR

USE OF RADIOACTIVE ISOTOPES FOR STUDYING THE SOLUTION OF SALTS IN WATER VAPOR AT HIGH PRESSURES AND TEMPERATURES

M. A. Styrikovich, I. Kh. Khaibullin and L. K. Khokhlov

A large amount of experimental material was accumulated, from which it was possible to derive the main solubility laws for nonvolatile substances in water vapor.

When the saturated vapor is in equilibrium with an aqueous salt solution the distribution coefficient takes the form

$$\Lambda = \left(\frac{\gamma''}{\gamma'} \right)^n,$$

where K is the distribution coefficient,

γ'' , γ' - are the densities of vapor and water;

n is a constant for a given material.

When the water vapor is in equilibrium with a solid phase the effect of vapor density on the solubility is given by a relation of the form:

$$C_n = A \gamma_n^m (t = \text{const}).$$

where C_n is the saturation concentration of the dissolved substance in the vapor; γ_n is the vapor density; A and m being constants for a given material.

It was thus found that the solubilities of various materials in water vapor are in the main determined by the properties of the solvent (vapor density and temperature). The properties of the salt only influence the absolute solubility. The phase equilibrium diagrams for the systems $\text{NaCl}-\text{H}_2\text{O}$, $\text{Na}_2\text{SO}_4-\text{H}_2\text{O}$, $\text{CaSO}_4-\text{H}_2\text{O}$ and $\text{SiO}_2-\text{H}_2\text{O}$ were drawn up by generalizing from the data of various investigators.

The relations and diagrams so derived enable one to compute the solubilities of various materials in the vapor phase at given temperatures, pressures and boiler water compositions, and hence to determine the conditions under which the salts are carried away by steam and the conditions under which they crystallize out from the vapor solution on the heating surfaces of the boiler and on the turbine blades.

On the whole, the use of radioisotope methods to study the solubilities of salts in steam is very effective, and the methods are at present being used by a number of research organizations in the USSR. The first papers dealing with this method were published abroad in mid-1956.

Kirzhizhanovskiy Power Institute,
Academy of Sciences, USSR.

STUDIES OF THE PROPERTIES OF STEAM AT 185 ATM PRESSURE, USING RADIOACTIVE ISOTOPES

L. S. Sterman, A. Ya. Antonov and A. V. Surnov

The relation of carry-over to volume vapor loading was studied on an experimental super-high pressure apparatus, the main functioning part in this having a vertical bubble column. The carry-over ω was determined as the ratio of activities in specimens of vapor condensate and "boiler" water. S^{35} in Na_2SO_4 was used as the tracer.

The experimental data were used to draw up curves relating the carry-over (this being from 0.004 to 1.2%) to load at a pressure of 185 atm.

It was found that over the measured loading range $R_v = 100 \text{ m}^3/\text{m}^3\text{-hour}$ to $750 \text{ m}^3/\text{m}^3\text{-hour}$ (no allowance being made for expansion) with a vapor space height of 450 mm and a pressure of 185 atm, there were three distinct laws relating carry-over to loading. The changes in the index n in the formula $\omega = CR_v^n$ occur at loadings in the vapor space of about 480 and $650 \text{ m}^3/\text{m}^3\text{-hour}$ (without allowance for expansion).

The experimental data on carry-over obtained at pressures of 17 and 185 atm show that the greatest weight loading of unit vapor volume accompanied by a constant carry-over of $\omega = 0.05\%$ may be attained at pressures of 130-150 atm.

Dzerzhinsky All-Union Research Institute of
Heat Technology

LABELED-ATOM METHOD FOR STUDYING THE WATER AND STEAM CONTENTS DURING THE SURFACE BOILING OF A LIQUID

P. G. Poletavkin and N. A. Shapkin

A tracer atom method for studying water and steam contents during surface boiling of a liquid is described, this being based on the use of a radioactive salt solution of very low concentration.

The method is a relative one. The experimental area was used to measure the γ -ray intensity from the tracer in the solution at the same site with and without surface boiling. The ratio of the measured count rates will represent the change in the water-volume content in the area with the experimental heater, from which it is easy to derive the vapor volume fraction during boiling.

A description of the experimental setup for studying the water and vapor contents during surface boiling is given, and the results are presented as calculated formulas and graphs for three different pressures, and for various unheated liquids and thermal and hydrodynamic regimes.

Measuring Equipment Laboratory,
Academy of Sciences, USSR.

USE OF RADIOACTIVE ISOTOPES FOR STUDYING THE FILTRATION OF LIQUIDS THROUGH POROUS MEDIA

V. V. Rachinsky

This communication is concerned with some theoretical and methodological questions in the investigation of the movements of a liquid labeled with a radioisotope in porous media (sorvents, soils, earths, building materials, etc.). The isotope method enables one the carry out more profound studies of fluid motion in porous media. E.g., the movement of a labeled liquid front can be followed directly with a radiometric apparatus as it moves within the porous medium, information on the mean flow velocity within the medium being obtained, as well as on the type of porosity and on other important properties, such as the hydrodynamic and molecular processes which occur.

Current chromatographic theory may be used to analyze the experimental data. The opinion has been expressed that only nonsorbed isotopes can be used to study filtration. But experiment and chromatographic theory show that labeled sorbable substances can be used successfully in such work when dissolved in a liquid. This extends the scope of isotope methods in this field. The rate of movement of a liquid in a porous medium may be determined from the half-concentration point of the S-shaped front when this is labeled with a non-sorbed radioactive isotope. When sorbable isotopes are used, the rate of movement of a liquid in a porous medium may be determined from the theory of chromatography via the motion of a point on the front formed by the labeled substance.

Experiments with P^{32} , Rb^{86} , Na^{24} , etc., were carried out to illustrate this method of studying filtration of water through porous media. The filtration of water through porous media of two sharply differing types was studied; the media were sand columns and columns of synthetic resins, which swell. The transfer of water through these two types of porous media was elucidated.

Williams Institute of Waterworks Engineers
Moscow

RADIOACTIVE METHODS FOR STUDYING THE FLOW OF LIQUIDS IN A POROUS MEDIUM

D. I. Leipunskaia and Ya. A. Pruslin

A method of gauging the saturation continuously was developed for hydrodynamic flow studies on models of porous media. The saturation with a given liquid was determined by the external γ -flux from a radioactive tracer introduced into the liquid in a suitable chemical form. The hydrocarbon phase was labeled with P^{32} ($T_{1/2} = 8$ days) as iodobenzene, the water phase being labeled with Rb^{86} ($T_{1/2} = 19.5$ days) as rubidium chloride with added carrier. The radiation was detected with a scintillation counter and a single-channel pulse-height analyzer. Measures were taken to ensure that the equipment worked in a stable fashion during prolonged experiments (some hours or more). The measurements were made with an accuracy of 2-3%. The method was checked from the emergent fluid balance, this showing that the measured γ -ray intensity corresponded to the saturation in the area used.

As the γ -ray counting was highly efficient, it was possible to work with large hydrodynamic models containing a large amount of liquid without incurring hazardous operating conditions. In practice, the distributions of liquid phases in the model during the flow can be detected continuously.

The nonstationary flow of a gasified liquid was investigated in cylindrical and parabolic model strata, as well as the mutual displacement of identical liquids (of kerosene by kerosene and water by water) and of a hydrocarbon phase by water.

All-Union Natural Gas Research Institute

USE OF RADIOACTIVE ISOTOPES FOR STUDYING THE HYDRODYNAMICS OF A LIQUID IN THE CONICAL ROTOR OF A PRECIPITATING CENTRIFUGE

M. A. Borts, L. S. Zarubin, V. S. Kaminsky and L. L. Korsak

Tracer methods appear to be a convenient and accurate way of studying the hydrodynamics of aqueous inorganic salt solutions in the conical rotor of a precipitating centrifuge. The experiments were carried out by filling the rotating rotor of a laboratory conical centrifuge to overflowing with a solution of labeled CaCl_2 .

After filling the rotor, a solution of the same specific gravity and viscosity which contained no Ca^{45} was poured in at a definite rate. The spillage was collected in receivers changed at fixed time intervals. When the addition of solution ceased, the solution remaining in the rotor was placed in a separate receiver; the relative specific activities of the starting solution, the spillage samples, and the solution remaining in the rotor were determined, and the volumes of the specimens were measured. Knowing the volume of the radioactive solution poured into the rotor at the beginning of the experiment, and the volumes of all spill samples, we were able to compute the amounts of the original solution ejected from the rotor during the time-periods corresponding to sample collections, from the relative specific activities.

The experimental data confirm the hypothesis that the solution originally poured into the rotor is gradually displaced, and that the velocities in various parts of the rotor are not the same. This agrees with the theoretical concept that the rapid liquid flow occurs in regions adjacent to the cylindrical surface of the liquid wall. The motion becomes slower on going away from the axis of rotation, and becomes inappreciable in the peripheral stagnant zone. The data also show that the flow velocity vector has both axial and radial components.

Changes were found in the liquid flow due to changes in process parameters (specific gravity and viscosity of solution, angular velocity of rotor). From a detailed analysis of the data, a new formula was proposed for use in the design of precipitating centrifuges with conical rotors.

All-Union Coal Enrichment and Briquetting
Research Institute

USE OF RADIOACTIVE ISOTOPES FOR STUDYING THE MOVEMENT OF WATER IN PEAT UNDER LABORATORY AND FIELD CONDITIONS

M. P. Volarovich, N. V. Churayev and B. Ya. Minkov

S^{35} -labeled Na_2SO_4 was used to study water filtration in peat. It was shown that S^{35} is only slightly absorbed by peat, and that diffusion of the tracer has no noticeable effect on the results.

The laboratory experiments on filtration through peat specimens of undisturbed structure were used to develop a method of determining the sizes of water-permeable pores and the rate at which liquid passed through them. Methods of determining the nonmobile and bound water in peat were proposed, so that the various types of water in turf could be defined more accurately by their mode of bonding. It was shown that peat contains a considerable amount of water (up to 35-40%) which does not participate in filtration.

Observations on the movement of S^{35} -labeled water were carried out under field conditions when the peat deposits dried out. Field methods were developed for observing the direction and velocity of water movement in peat. These methods were used to study water filtration in peat areas dried by deep drainage.

The results of this work, which was mainly directed to developing methods of studying the water properties of peat with radioactive tracers, can be used to perform extensive operations in this field.

Moscow Peat Institute

USE OF RADIOACTIVE ISOTOPES FOR STUDYING RIVER DREDGING PUMPS

M. M. Arkhangelsky

Drainage scheme design requires a knowledge of river silts and their particle size distributions. To find the amount of silt per unit volume and the distribution parameters, it was proposed to use simultaneous light and γ -ray absorption measurements. The silts were assumed to consist of spherical particles, identical in density but different in size. The particle sizes were assumed much greater than the wavelength of light.

It was shown that if the particles sizes vary continuously over a range between r_1 and r_2 , the optical density produced by the particles contained in the unit volume may be expressed in the form

$$D = 0.43 \pi \int_{r_1}^{r_2} f(r) r^2 dr, \quad (1)$$

where $f(r)$ is the size distribution function.

It was shown that on the above conditions the absorption of a collimated γ -ray beam by suspended particles will depend on their volume or weight concentration. A quantity D_q , analogous to the optical density, may be derived for γ -rays from the following relation

$$D_q = \frac{1}{l} \ln \frac{I_0}{I_1} = \tau_0 V, \quad (2)$$

where l is the layer thickness irradiated;

I_0 is the incident radiation intensity;

I_1 is the exit radiation intensity;

ρ is the particle density;

τ is the mass absorption coefficient for the material in the particles.

The total particle volume may be expressed as

$$V = \frac{4}{3} \pi \int_{r_1}^{r_2} f(r) r^3 dr. \quad (3)$$

Thus the two Equations (1) and (3) are obtained, of which the left-hand sides can be determined by simultaneous independent measurement, i.e. light and γ -ray absorption.

A solution is given for the case where the silt distribution curves approximate to Maxwellian form:

$$f(r) = A r^2 e^{-B r^2}.$$

By solving the equation pair

$$D = 0.43 \pi \int_{r_1}^{r_2} A r^4 e^{-B r^2} dr,$$

$$V = 0.57 \pi \int_0^R A r^2 e^{-n r^2} dr,$$

by series expansion, the A and B parameters of the curves are derived. This solves the problems of finding the silt concentrations and distribution curves.

Experimental data are given which demonstrate that the method is of satisfactory accuracy.

Moscow Regional Pedagogical Institute

USE OF RADIOACTIVE ISOTOPES FOR STUDYING THE MECHANISM OF A DRYING PROCESS

A. I. Veinik and A. S. Shubin

In this work an attempt was made to use radioactive tracers in studying drying-process mechanisms. Two methods are proposed for studying the phase transformation of water during experimental drying - a stationary and a nonstationary one. In both cases the specimens were moistened with a solution of a radioactive salt.

The stationary method was used for studying the phase transformation-zone distribution in the body and for defining local and integral criteria of phase change from the rate of change of activity in various layers of the material. The water evaporates both within the material and at the surface during drying. For each amount of water evaporated at any point a corresponding quantity of radioactive salt was deposited. The amount of salt deposited within and on the surface of the material was determined from the rise in activity measured at defined time intervals. In the nonstationary method, the changes in local activity indicate not only the rate of vapor formation, but also moisture content changes due to movement of liquid.

By such methods the effects of various factors on the phase-transformation criteria were established. A formula was deduced from which the rate of internal evaporation in any layer of material may be calculated.

Moscow Food Technology Institute

USE OF RADIOACTIVE ISOTOPES FOR STUDYING THE MOVEMENT OF THE GLASS IN THE WELLS OF GLASS FOUNDRY OVENS

V. A. Dudrovsky

By using charges labeled with Ca^{45} or Sr^{90} in a glass furnace it was found that the glass bodies formed from parts of the charge introduced at any one point in the furnace became distributed over the whole furnace as separated fragments moving with various velocities. The main flow into the glass body was not bound to occur from the side on which the charge was inserted.

It was also found that in continuous glass-rolling furnaces there was a small primary surface flow in the glass body which took place over the whole furnace with a velocity of about 60-70 m/hour. Two distinct circulations between feed point and the point of highest temperature took convective courses. The first cycle took about 45 min and the second about 5 hours. There was also a circulation between take-off and hottest points, this occurring at some depth below the surface.

The main body of the glass which is formed from the charge in the feed zone is at once submerged at some depth in the furnace, and thus reaches the hottest area whence it passes to the surface. Only then does it begin to take part in the circulating currents.

When the flows resulting from the feedpoint encounter those from the take-off point at the hottest area, some part of the glass which was circulating in the space between feed and hot-points passes over a "temperature barrier" and is partially taken off in the rolled strip, and some part begins to circulate in the furnace outside this barrier.

The experiments showed that the opinion held among practical operators that the glass formed from one portion of charge is taken off almost as a whole, is incorrect. Parts of the charge circulated in the furnace for 22 hours and completed at least 30 cycles in the day. This leads to the glass body gradually becoming homogeneous instead of being stratified as at the moment of formation.

Ukrainian Branch of the All-Union
Glass Research Institute

USE OF LABELED ATOMS TO DETERMINE THE SPECIFIC SURFACES OF QUARTZ AND CEMENT POWDERS BY THE SORPTION METHOD

V. S. Kudryavtsev

The method used is based on the monomolecular adsorption of the radioactive isotopes of strontium, calcium, tungsten, cesium and cobalt. The adsorbent was powdered Volk cement clinker and pure crystalline quartz of dispersions 1,000 and 10,000. The adsorption isotherms were obtained, these being the relation between the amount of substance sorbed from a neutral solution per gram of sorbent at equilibrium, and the concentration, derived from the equilibrium distribution of a tracer between sorbent and solution. The area of the sorption curve in the rising direction corresponded to the equilibrium sorption distribution of tracer material between sorbent and solution. As the concentration of the solution increased, the curve passed into a straight-line region with a very small slope - i.e. a plateau characteristic of monomolecular adsorption, when the adsorbent surface is covered by a layer one molecule or one ion thick. The height of the plateau will depend on the degree of ionic or electronic cloud interaction.

The amount of material adsorbed by one gram of solvent at the beginning of the plateau represents the sorption capacity of that substance on that sorbent under monomolecular adsorption conditions. When the sorption isotherms were drawn up the amount of sorbed material in g-atoms per g of sorbent was calculated at the various concentrations from the formula

$$a_m = \frac{(I_{\text{init}, i} - I_{\text{eq}, i}) \cdot C_{\text{init}, i} \cdot V}{I_{\text{init}, i} \cdot M \cdot A_{\text{at.wt}}}$$

where $(I_{\text{init}, i} - I_{\text{eq}, i})$ is the difference in the activities of 1 ml of solution of given concentration before and after sorption;

M is the weight of sorbent used in the solution;

$A_{at, wt}$ is the atomic weight of the sorbed element;

$C_{eq, i}$ is the equilibrium concentration of the solution after sorption (the initial concentration being $C_{init, i}$).

The equilibrium concentration is determined from the relation

$$C_{eq, i} = \frac{I_{eq, i}}{I_{init, i}} C_{init, i}$$

The specific surfaces of the powders were computed from the formula

$$S = K \frac{I_{eq, i} V}{I_{init, i} \cdot M \cdot A_{at, wt}} N \omega^{\theta}$$

where $K = e^{\frac{0.693}{T} - t}$ is the decay correction;

N is Avogadro's number;

ω^{θ} is the effective area occupied by an ion on the surface of the adsorbent.

Stable neutral solutions of strontium nitrate ($Sr(NO_3)_2$), sodium tungstate (Na_2WO_4), calcium chloride ($CaCl_2$), cesium chloride ($CsCl$) and cobalt sulfate ($CoSO_4$) were prepared, the appropriate isotopes being added to give activities of 2000-4000 c/min per 250 ml. 5 ml volumes of varied concentration (0.5-25 mg/ml) were treated with 20-30 mg of adsorbent. Quartz powder was used as standard. The activities were measured before and after sorption mostly on liquid specimens of 0.5 ml. in a vessel placed 2-3 cm from the window of a Gelger-Müller counter. The time required for equilibrium between sorbent and solution was established experimentally, being between 40 and 50 sec when stirred vigorously. Further sorption did not occur on prolonged contact. The sorption curve was found to rise to a definite level, this being explainable from hydration effects. The isotopes of Sr, Ca, Cs, Co, WO_4 were found by desorption from quartz powder to be physically adsorbed, while with cement powder, these isotopes, except Cs, were bound by chemical forces. Adsorption isotherms were drawn up, and the specific surfaces of the quartz and cement powders were determined. The sorption curves for Sr and Cs were of the same type, being stepwise in character and having a marked plateau, this being due to the successive formation of mono- and multi-molecular layers. The sorption isotherms obtained with WO_4 , Ca and Co were predominantly Langmuir in form. The Co adsorption isotherm differed by having a smooth onset of the plateau and an inappreciable formation of multilayers. The high potentials developed at the surfaces by adsorption of Co and Ca cations evidently prevent the formation even of a second layer.

The specific surface of the sorbent did not depend on the isotope used, but the sorption capacity had a tendency to rise when isotopes of small ionic radius were used, which must be supposed due to considerable penetration into micropores; hence the specific surface of the sorbent, as derived from the sorption capacity, was determined more accurately and had a greater numerical value. Thus, discrepancies in the numerical values of the specific surfaces of the same sorbent derived from the use of various isotopes may be explained by the difference in their ionic radii. The fact that the true ionic arrangement on these surfaces is unknown may also be important.

The experimental data demonstrate that the specific surface of a sorbent increases with its dispersion.

It is supposed that the most correct numerical values for the specific surfaces of quartz and cement were obtained by the adsorption of Cs and Co, since the curves for these have marked plateaus.

Rostov Institute of Constructional Engineering

USE OF THE RADIOACTIVE SULFUR ISOTOPE S^{35} FOR STUDYING THE SULFATE CORROSION OF CONCRETE

V. M. Moskvina and I. I. Kurbatova

The stabilities and durability of cement mortar and concrete in "aggressive" (corrosive and mechanical attack) surroundings depend to a considerable extent on their structures - which in the first place are specified by their permeabilities. It is of interest to establish (1) the speed and depth of penetration when studying building corrosion in a sulfate environment, (2) the distribution of the sulfate ions in thick material, and (3) the sites and conditions where hydrated calcium sulfo-aluminates and gypsum form.

For this reason, research on a convenient method for studying permeability was undertaken using S^{35} . A special shield was constructed which, together with a type B unit, was used to measure the activity in thick specimens. A special apparatus was constructed for powdered specimens impregnated with radioactive solutions.

The distribution of sulfate ion in the capillaries of cements and sand concretes of varied compositions was studied by this method, and it was shown that the amount of sulfate ion entering thick materials depended to a large extent on their structures. The kinetics of sulfate ion penetration into cement-sand concretes of varied compositions were also studied.

This method enables one to determine the depth of penetration and the type of distribution in the concrete for other attacking ions. Together with other methods of studying concrete corrosion they enable one to define the effect of concrete structure and permeability on the penetration of sulfate solutions into thick concrete, and hence on the sulfate corrosion processes. The concrete density required to ensure stability and durability can be deduced from these data.

Future work on this will give a deeper insight into the process of concrete corrosion and enable one to develop simple and convenient methods of protecting concrete in corrosive media.

Central Industrial Building Research Institute.

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ACADEMY OF SCIENCES USSR
CENTRAL COMMITTEE ON UTILIZATION OF ATOMIC ENERGY
COUNCIL OF MINISTRIES, USSR

ALL-UNION CONFERENCE ON THE APPLICATION OF
RADIOACTIVE AND STABLE ISOTOPES IN THE
NATIONAL ECONOMY AND SCIENCE

ABSTRACTS OF PAPERS GIVEN IN THE SESSION ON BIOLOGY,
MEDICINE, AND AGRICULTURE

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Editors

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I. GENERAL MEETING OF THE SECTIONS

THE SYNTHESIS OF THE PEPTIDE LINKAGE IN PROTOPLASMIC STRUCTURES

N. M. Sisakyan

The use of the isotopic method in biochemistry led to clarification of a number of important regularities in the chemistry of the transformation of substances within the cell. In particular, for the last ten years the questions of the formation of the peptide linkage and the rate of replacement of proteins in the organism have been the subject of detailed research.

Experimental data have been obtained through the study of the synthesis of the peptide linkage in the protoplasmic structures of plant and animal cells. The question of the intensity of the biosynthesis of protein in the growth processes of the organism has been investigated. Results have been considered which characterize the synthesis of the peptide linkage by means of both the data of isotopic labelling and data obtained by the usual methods of biochemistry. The question of the significance of free amino acids and peptides in the synthesis of proteins in the structural elements of animal and plant cells is being investigated.

The experimental results lead to the following conclusion.

Comparative research on the synthesis of the peptide linkage in the protoplasmic structures of plant and animal cells reveals not only points of similarity, but also a definite difference between structures of animal and plant origin.

A mixture of amino acids stimulates the inclusion of glycine in proteins of plant cell structures just as in the protein structures of the coelomic fluid of the silkworm. The addition of ATP strengthens the stimulating effect of the amino acids on glycine inclusion.

The formation of peptides is an intermediate stage in the inclusion of glycine in the coelomic fluid proteins. In plant cell structures protein synthesis takes place with the participation of peptides and amino acids. For plant cell structures there is not always observed a correspondence between the intensity of the inclusion of amino acid and the accretion of protein.

Thus the synthesis of protein, in all probability, is not confined to any one structural pattern, and is accomplished with varying intensity in all the structural elements of the cell.

The A. N. Bakh Institute of Biochemistry of the
Academy of Sciences of the USSR

THE APPLICATION OF THE ISOTOPIC METHOD IN SOIL RECLAMATION RESEARCH

I. N. Antipov-Karataev

One of the basic problems of irrigation agriculture is the problem of the balance of water, which is controlled by the level of moisture content in the root-containing soil layer. At the present time rapid methods for

determining the moisture content of the soil have been worked out, based on the use of radioactive emanations (the neutron and gamma-ray methods).

In order to devise a watering schedule, it is necessary to know the lowest level of reserve moisture in the root-containing layer of soil; this is determined by the method of salt accumulation, using radioactive isotopes as indicators. The second limit of soil moisture which is accessible for plants is the so-called plant reserve moisture, determination of which is accomplished by botanical methods according to the external condition of the plants. For the determination of this reserve moisture from the rate of water intake into the plant, special isotopic methods are being worked out using different forms of heavy water as indicators.

The question of the quality of irrigation water occupies an important place in the practice of irrigation agriculture. In evaluating the quality of water according to its degree of mineralization, the isotope method can be employed. It is extremely important to know the magnitude of the so-called "critical" ratio of sodium and calcium ions in the composition of the salts of irrigation water. Its numerical value is found by the method of adsorption-desorption curves with the use of Ca^{45} as an indicator. This method is employed in selecting rational agricultural techniques in the reclamation of saline soil.

In calculating the parameters of drainage equipment and in estimating the work of existing collector drainage systems, the use of radioactive isotopes could correct and perfect the theoretical principles, at the same time giving concrete data to be used for purposes of calculating. The isotopic method has been employed to determine the capacity of a soil for chemical exchange using Ca^{45} , especially soil rich in carbonates, but also acidic soil.

In recent years there has arisen the task of researching the processes of accumulation and adsorption of Sr^{90} , Cs^{137} etc. by the soil. In connection with radioecological research, a special study of the questions of the exchange competition between strontium and calcium ions is extremely urgent.

Research has shown that the decomposition processes of organic substances may be regulated by a system of special agricultural engineering methods. Research on this problem promises to provide cardinal theoretical conclusions of a general nature on the knowledge of top soil as well as the fundamental principles of a new system of cultivation of irrigated soil.

The V. V. Dokuchaev Soil Institute of the
Academy of Sciences of the USSR

THE USE OF RADIOACTIVE CARBON C^{14} IN THE STUDY OF THE MECHANISM OF THE BIOSYNTHESIS OF RUBBER AND ITS CONCOMITANT SUBSTANCES IN THE KOK-SAGHTZ PLANT

E. A. Shilov, I. A. Dushchkin*, I. G. Vyvalko, G. M. Lushchevskaya,
K. I. Matkovsky, G. G. Savinov and A. A. Yasnikov

Neutral aqueous solution of different compounds containing carbon - C^{14} - were introduced into the kok-saghtz plant via the leaves or by injection into the roots.

At specific time intervals fractions of rubber, resins, carotene and water-soluble substances were isolated from the plants treated with the solutions of radioactive compounds. The specific and general radioactivity of each of the fractions was determined. In parallel experiments the radioactivity of the carbon dioxide isolated was also determined.

As a result of the research it was discovered that the compounds introduced are drawn in according to the respiratory cycle and in 5 to 6 days are 50 to 80% converted into CO_2 . By the fifth day of the experiment only 10 to 15% of the radioactive carbon introduced remained in the water-soluble substances. 0.5 to 3% of the C^{14} was transferred to the water-insoluble substances - rubber, resins, carotene and cellulose.

*Deceased

Cellulose acquired the greatest radioactivity in experiments with marked α -glucose - C^{14} . The radioactivity of cellulose in experiments with other compounds (acetic acid, levulinic acid, alanine, pyruvic acid) was 8 to 20 times less than the radioactivity obtained with labeled glucose.

The radioactivity of cellulose, both in the leaves and in the roots, reached its maximum value 8 to 10 days after the first radioactive substances were introduced, and then decreased; this indicates the participation of the newly formed cellulose in metabolic processes.

Of all the compounds investigated, alanine - C^{14} imparted the greatest activity to rubber. Atoms of C^{14} from different sugars, acids of the Krebs cycle (pyruvic acid - C^{14} and acetic acid - C^{14}), levulinic acid - C^{14} , acetoacetic acid - C^{14} , acetone - C^{14} and glyceric acid - C^{14} entered into rubber to approximately the same extent (3 times less than those from alanine - C^{14}). To a significantly lesser degree C^{14} from molecules of β -methylcrotonic acid - C^{14} was transferred to rubber; pyruvic acid - C^{14} , alanine - C^{14} , α -gluconic acid - C^{14} and benzoic acid - C^{14}OH imparted practically no radioactivity to rubber.

On the basis of the distribution of radioactivity the conclusion is drawn that in the bio-synthesis of rubber a two-carbon molecule takes part (acetaldehyde complexed with an enzyme), formed after the decarboxylation and deamination of alanine.

Carotene acquired significant radioactivity in experiments with acetic acid - C^{14} , alanine - C^{14} , acetone - C^{14} , acetoacetic acid - C^{14} and glyceric acid - C^{14} . Other labeled compounds imparted less activity to carotene. As Grob and Butler have shown, acetic acid is an intermediate substance in the synthesis of the isoprene chain of the carotene molecule. It is possible that acetone - C^{14} and alanine - C^{14} participate in the synthesis of the ionone ring of carotene.

The probable mechanism of the formation of rubber and carotene includes the condensation of a two-carbon molecule with trioses or their derivatives, together with the participation of the corresponding enzymes.

The Institute of Organic Chemistry of the
Academy of Sciences of the USSR

THE ACCUMULATION AND RESERVE OF ASSIMILATED PHOSPHATES IN SOILS IN RELATION TO THE RESIDUAL ACTIVITY OF PHOSPHORUS FERTILIZERS AND THE NEED FOR THEM IN THE AGRICULTURE OF THE USSR

A. V. Sokolov

The quantity of phosphorus introduced into fertilizers in a number of sections of the country exceeds several times the amount of phosphorus removed in harvesting the crops. In a number of field experiments a prolonged effectiveness was demonstrated not only of phosphate meal but also of water-soluble superphosphate. The analyses of soils on which phosphates were systematically employed indicate an accumulation in the soil of assimilated phosphates.

The question of over-phosphorization of the soil (in certain sections) with surplus doses of phosphorus fertilizers is gaining an increasing amount of the attention of agricultural chemists.

The question of the utilization of the unused phosphates which remain in the soil from fertilizers previously employed is significant at the present time to the national economy, because on its solution depends not only the practice of fertilization, but also the planning of production and consumption of phosphorus fertilizers for different sections of the USSR.

The application of the radioactive isotope of phosphorus to agricultural chemical research enables us now to review our ideas on the utilization of phosphorus in the soil.

The addition of radioactive tracers in the soil analyses of agricultural chemistry altered our ideas on the subject toward an increase in the reserves of active phosphates in the soil.

The addition of radioactive tracers in botanical experiments in which phosphorus fertilizers were systematically introduced led to establishing the existence of a strong accumulation of assimilable phosphates in the soil, which fully explains the prolonged effectiveness of the fertilizers. The use of labeled fertilizers in the experiments altered our notion of the actual coefficient of the consumption of phosphorus from the fertilizers. The use of isotopic phosphorus extracts made it possible to determine the active convertible phosphorus in the soil.

The notion of a deleterious retrogression in the soil of water-soluble phosphates (superphosphate) and of a low coefficient of their utilization is not in agreement with present-day attitudes on the conversion of phosphorus fertilizers in the soil and the degree of their assimilation in different types of soil.

At the present time it is necessary to check with respect to the degree of over-phosphorization in the areas where phosphorus fertilizers are used intensively by setting up experiments with controlled dosages of phosphates and conducting soil analyses with isotopic tracers.

The use of the isotopic method in agricultural-chemical and soil research led not only to a clarification of the roles of the different methods of application of fertilizers (the size of the granules of superphosphate, the non-root sources of nutriment etc.), but also to a change of the general principles of supplying phosphorus to plants and of the use of phosphorus fertilizers in the agriculture of the USSR.

The Scientific Institute of Fertilizers,
Insecticides and Fungicides

THE EXPERIMENTAL CULTIVATION OF SILKWORM LINES MARKED ACCORDING TO SEX USING ROENTGEN RAYS

V. A. Strunikov and L. M. Gulamova

An exact determination of the sex of the silkworm in the egg stage makes it possible to cultivate industrially only individuals of the more productive male sex; this increases the output of silk production by approximately 20 to 25% without additional expenditure of work or of mulberry leaves. Such a large increase in productivity is explained by the fact that the males elaborate 20 to 30% more silk and are 10 to 15% more viable than the females. Furthermore, the separation of the eggs according to sex makes it possible for the breeding stations to prepare only the one most productive hybrid strain, the eggs of which should be practically unmixed with pure breeds; this also leads to an increase in productivity of industrially cultivated silkworms.

The advance separation of the eggs according to sex by automatic machines in the spring replaces the laborious and very inexact separation of the breeding stock according to sex in the cocoon stage.

In Japan, after 11 years of uninterrupted research work, several lines marked according to sex have been derived, one of which, marked in the egg stage, has been put to industrial use.

In view of the considerable economic significance of breeds marked according to sex, Japanese law forbids their exportation. For this reason Soviet sericulture had to create its own breeds marked according to sex in the egg stage. In 1955 work was begun to create lines marked according to sex. A line developed in the laboratory of Professor B. L. Astaurov, one hereditary feature of which was white eggs, served as the raw material.

In 1956, by means of the translocation of an autosome onto the W sex chromosome, a silkworm line was obtained from the dark eggs of which females develop, and from the white eggs, — males.

The translocation was accomplished by the action of Roentgen rays on pupae of the bivoltine breed No. 111 of the Central Asian Scientific Research Institute of Sericulture with a dosage of 3000 r. Exposure conditions: voltage, 100 kilovolts; current strength, 10 amps.; distance, 22 cm; filter, 3 mm gauge aluminum.

The butterflies issuing from the exposed pupae were mated with males which developed from white eggs; the second generation females obtained were then mated with males of the same type.

Out of 1882 second-generation families checked according to sex, there appeared only one laying, with a reproduction ratio of 912 to 3, from the dark eggs of which there issued females exclusively, and from the white eggs, males. This family was the initial one used to create a line marked according to sex in the egg stage.

A check on sex in the fourth generation of the line marked according to sex showed that from the dark-colored eggs 3340 females and no males had developed, while from the white eggs, 3190 males and 1 female. The egg specimens for the check on sex were taken equally from 111 layings, combining approximately 55,000 eggs.

The check, executed by the Tbilisi Scientific Research Institute of Sericulture, the Ukrainian Sericulture Station, the Samarkand Sericulture Station, and the Central Asian Scientific Research Institute of Sericulture, confirmed the feasibility of obtaining from the white eggs an exclusively male line marked according to sex.

The viability of the line marked according to sex has been satisfactory in the first four generations. With the aim of widening the choice in the future of original lines marked according to sex for the creation of industrially valuable breeds, also marked according to sex, work has been done to obtain additional lines marked according to sex in the egg stage by white eggs and by eggs of a new color — violet.

The Central Asian Scientific Research Institute
of Sericulture

THE INITIAL MECHANISMS OF THE BIOLOGICAL EFFECTS PRODUCED BY IONIZING RADIATIONS

A. M. Kuzin

1. In considering the initial processes taking place in a cell exposed to radiation, it is necessary to proceed from present-day notions on the properties characteristic of the state of a substance in a living cell.

2. The high molecular weight polymers which make up the basis of living matter are not found in the cell as free molecules, distributed without order in an aqueous medium. A characteristic property of living matter is the ordered organization of these high molecular weight polymers in submicroscopic and microscopic structures.

3. The influence of ionizing radiation on the ordered systems of high molecular weight molecules is particularly significant to an understanding of the nature of the initial processes produced by radiation.

4. If it is taken into account that a significant quantity of water in the living cell enters directly into the formation of micro-structures, one must assume that about 50% of the energy absorbed is used in activating the water molecules and about 45% in the direct activation of the micro-structured cellular material.

5. The ultimate effect of the influence of radiation depends upon the presence of a complex of intensifying mechanisms in the micro-structures exposed to radiation.

6. The physical means of intensification is based on the possibility of the transfer of absorbed energy within the spatially ordered macromolecular systems and the emergence of long-lived excited states of the macromolecules.

7. The chemical means of intensification is found in the possibility of forming chain reactions in the structures under consideration.

8. The biochemical means of intensification consists in the alteration of the ordered distribution of enzymes in the systems exposed to radiation, which results in a further disturbance of the state of the system at the expense of enzymatic activity.

9. The chief significance of radiation effects lies in a change in the structures formed from nucleoproteins and, linked with this, a change in the synthetic processes of the systems exposed to radiation.

The Institute of Biophysics of the Academy of Sciences of the USSR

BIOPHYSICAL RESEARCH ON RADIATION REACTIONS OF ORGANISMS

G. M. Frank

The most difficult task of radiobiology is the analysis of the mechanisms, largely still unknown, of the radiation of the higher organisms — the mammals. With the greatest possible understanding of the primary processes as a goal, it is necessary in this case to carry out simultaneously three mutually supplementary research plans. The first of these would be a small-scale operation on simple systems; secondly, a study of reactions in parallel cases — on the one hand in simple systems, and on the other hand in complex organisms under identically variable experimental conditions; thirdly, the development of new research procedures which would permit the direct observation in the whole organism of, if not the primary, then in any case the initial transformations.

In considering the primary processes, it can be maintained at the present time that their nature is far from limited, according to a well-developed plan, to the radiolysis of water and the formation of free radicals with the participation of oxygen. This mechanism presupposes the necessary presence of ionization. In contrast to a pure aqueous medium, however, in the actual biological substrate a substantial role may be played by the excitation process, leading to a splitting of chemical bonds either directly or through secondary ultraviolet radiation.

The underestimation of the true reaction mechanisms is obvious; well-known facts from the current literature, testifying to the effect of shielding and directed transmission of absorbed energy in dry high polymers, speak of the substantial role of such mechanisms. Very probable is the existence of chain processes, in particular in the lipid phase.

All these phenomena acquire particular significance, given the real condition of biological structures with a highly organized molecular construction and considerable "local" concentration of specific substances.

Simultaneously with structural heterogeneity, it is necessary to evaluate also the role of the mobility of these structures in the mechanisms of radiation reactions. As has been successfully established, while for the direct radiation hemolysis of erythrocytes *in vitro* exceptionally large dosages are required, then under the same conditions, but when the changes which in time take place are noted (the shattering of the structure), those dosages prove sufficient which produced a severe radiation effect *in vivo*.

By using a number of methods on the entire functional organism, the initial physicochemical and biochemical transformations can be revealed and analyzed. The most essential measurements here *in vivo* are the electrical parameters of living tissues and the rate of oxidation processes in tissue. By shifting the localization of the action, in particular by exposing small fields to radiation, one can successfully differentiate primary and secondary processes. In this way it was successfully established that the early depression of oxidation processes is the result of direct and immediate action on the irradiated tissue.

These disturbances should be compared with the peculiar heterogeneity of the living substrate and the mobility of the living structures.

The Institute of Biophysics of the Academy of Sciences of the USSR

IONIZING RADIATION AND CELLULAR METABOLISM

M. N. Meisel

Complex cytological, physiological and biochemical research on the transformations in cells exposed to radiation shows that, together with early injuries to the nuclei, the functions of the protoplasmic structures — the mitochondria and very probably the microsomes — are also substantially disturbed.

Nuclear and cytoplasmic nucleoprotein structures and nucleoproteins differ significantly in their reactions to ionizing radiations. These reactions can be brought to light with comparatively small doses of radiation by the use of luminescent methods.

One of the early manifestations of radiation effects in a cell is the suppression of oxidative phosphorylation, accompanied by an inadequate decrease in cell respiration. The obstruction of the mitochondria in living cells with fluorescent stains and certain substances reducing surface tension decreases the suppressing action of radiation on respiration and phosphorylation and increases the survival rate of the cells.

In radio-biological research on the cellular level, considerable significance is accorded to the study not only of a protective effect in relation to the survival rate of the cells but also to the protection from radiation of the separate cellular structures and functions which are most subject to injury.

Together with the already well-known changes in cell metabolism under the influence of radiation, there clearly appears an earlier and significant disturbance in those metabolic stages concerned with carbon and nitrogen exchange, in particular in the processes of amination and transamination of ketonic acids.

Research on the action of radio-mimetic substances on cell metabolism affords a wider possibility for the understanding of the mechanism of the biological action of radiation. According to the author's data, substances of the azotiprite type are somewhat different in their cytophysiological action from ionizing radiation.

The Institute of Microbiology of the Academy of Sciences of the USSR

CHANGES IN THE BIOLOGICAL PROPERTIES OF BLOOD IN ANIMALS EXPOSED TO RADIATION

P. D. Gorizontov

Over fifty years ago the presence of toxic substances in the blood of humans and animals exposed to radiation was first demonstrated. The results obtained however, after a great deal of supplementary research on blood transfusions from irradiated to nonirradiated animals, proved inconsistent. This can be explained by the unreliability of the methods used as evidence of toxemia and by a faulty understanding of the very problem of toxemia.

By employing the blood transfusion method and the method of perfusion of separate parts of the irradiated organism, the change in biological properties of the blood in dogs was studied. The research showed that toxic substances develop in the blood of irradiated animals and that different parts of the body differ in importance with respect to the change in biological properties of the blood.

Experiments with the perfusion of an extremity of an irradiated animal showed that the tissues (bone marrow) of such an organism secrete into the blood biologically active substances which are capable of changing the composition of the peripheral blood and the cellular composition of the bone marrow in nonirradiated animals.

The perfusion of the liver of an irradiated animal induced a lowering of the quantity of reticular cells and a change in the blood protein fraction in the nonirradiated animal.

A study of the biological properties of blood in dogs at different stages in the development of radiation sickness showed an increase in vasoconstrictor substances in the first stages and the emergence of vasodilator substances in the later stages. Vasodilator substances appear first of all in the blood of the jugular vein.

A test of the toxic properties of the blood of irradiated animals, performed on mice whose adrenal glands had been removed, made it possible to establish that blood taken during the first 24 hours after irradiation promotes the survival of animals upon which adrenalectomies have been performed, while that taken on the second or third day hastens their death. This also indicates a change in the biological properties of the blood of irradiated animals.

By using the method of general, or total, irradiation of intact rats and rats which had been adrenalectomized, the participation of the pituitary-adrenal system in the development of certain manifestations of radiation sickness was demonstrated. This proves that the role of the endocrine glands in the changes in biological properties of irradiated animals cannot be excluded.

The Ministry of Public Health of the USSR

THE NATURE OF THE PRIMARY GENETIC CHANGES PRODUCED BY RADIATION

N. P. Dubinin

1. The problems of radiation genetics are linked with a number of vital tasks confronting present-day science and practice. Among them are these particularly important questions: the danger of radiation to human heredity; hereditary changes in the objects of selection in microorganisms, both plant and animal; the possible role of damage to hereditary structures among the causes producing radiation sickness; and others. The basic theoretical problem, the solution to which is most important to work in all divisions of radiation genetics is the question of the nature of the primary genetic effects of radiation, that is, the changes produced by radiation in the nucleoproteins, which represent the hereditary structures of the cell.

2. At the initial stage in the study of radiation "spot" mutations and structural mutations of chromosomes, the concept of direct radiogenetic transformations was first worked out. Basic experiments were conducted to investigate the relationship between the frequency of different types of mutations and the dose, type and strength of the radiation.

3. Experiments on the influence of the conditions of the medium on the effect of ionizing radiation on heredity revealed that the genetic effects of radiation are linked to a lesser extent with the direct activation of the molecules in the hereditary structures than with the cause of their chemical transformation. The cause of the appearance of radiogenetic changes, as a rule, is a chain of physical and radiochemical processes. This circumstance produces the influence of the ionizing radiation on heredity, mainly by a controllable process.

4. The principal trends of the research which is bringing to light the radiochemical nature of the primary genetic changes produced by radiation are the following:

Clarification of the role of oxygen, infrared rays, physiological conditions and other factors modifying the induction by ionizing radiation of spot mutations and structural changes of chromosomes;

The problem of protecting the hereditary structures from ionizing radiation on the basis of data on the radiochemical nature of mutations;

The radiochemical principles of the indirect action of ionizing radiation on molecules of the desoxyribonucleic acids;

The significance of the comparative analysis of the nature of radiogenetic changes and the process of producing mutations with ultraviolet and visible light and by chemical factors; the mutagenic aftereffect of the irradiated medium; photoreactivation; fluorescent substances and the mutagenic influence of visible light; the problem of the specificity of different mutagenic factors;

Experiments with dry seeds and at the temperature of liquid air; injection into the cell of the radioactive isotopes P^{32} , S^{35} , and C^{14} .

5. Experiments conducted by the introduction of nonmutagenic compounds into the cell, which become mutagenic after absorbing the energy of a specific nonmutagenic type of radiation, are making possible an analysis of both the direct action of radiation (absorption of photons by the molecules of a specific substance introduced into the cell) and the indirect effect (a chain of reactions from the primary activated molecules to the chemical transformations in the hereditary structures). As a whole, to establish the nature of the primary genetic changes produced by radiation, a many-sided study of radiational, chemical, biochemical and physiological induction of mutation is required.

6. There is the problem of the danger of ionizing radiation to human heredity in the light of data on the absence of the threshold dose which would induce primary radiogenetic changes, as well as the problem of cumulative hereditary damage in the presence of the chronic action of small doses of radiation. There is the question of possible hereditary damage to humans as the chief danger in the use of atomic energy, and the question of the size of safe doses in connection with the danger of hereditary damage. There is the task of working out the experimental and theoretical principles of the question of the influence of radiation on human heredity.

The Institute of Biophysics of the Academy of Sciences
of the USSR

II. RADIOBIOLOGY

THE INFLUENCE OF IONIZING RADIATION ON THE FACTORS DETERMINING THE COMPOSITION AND PROPERTIES OF THE IMMEDIATE NUTRITIVE MEDIUM OF ORGANS AND TISSUES OF LIVING ORGANISMS.

L. S. Shtern

Among the phenomena characteristic of the action of ionizing radiation on the animal organism, an object of particular interest is the changes in the composition and properties of the immediate nutritive medium of the organs and tissues (the intercellular or tissue fluid) and in the factors determining its composition and properties - the histohematic barriers and metabolism.

The disturbance of the normal state of the histohematic barriers, the hematonephalic especially, has considerable significance for the preservation of the relative uniformity of the immediate nutritive medium of corresponding organs, as well as for establishing the essential humoral link between separate organs and the coordination of their functions in the organism.

In studying the permeability of histohematic barriers, the tracer atom technique was employed. It has been established that the change in the functional state of histohematic barriers is related to the number of previous disturbances induced by roentgen irradiation. After the total irradiation of rats with a dose of 800 r, the increase in permeability of histohematic barriers took place in different tissues in different periods of time: in the liver in 1 minute, in muscle - 15 minutes, and in the brain - 45 minutes. Within 2 to 3 days after irradiation, a sharp decrease in permeability was observed.

A sharp decrease in permeability of the placental barrier and the histohematic barriers of the fetus were observed in rabbits in the first two hours after total irradiation with a dose of 1000 r. This effect was obtained, as a rule, in all stages of fetal development, but in the latter stages was somewhat more weakly marked.

Metabolic changes are related to previous disturbances produced by roentgen irradiation.

After the total irradiation of rats with doses of 800 r, the inclusion of P^{32} in the acid-insoluble phosphorus fraction in both brain and liver was reduced. This reduction was apparent in the first few minutes after irradiation and was particularly clearly marked on the third day.

Also studied was the influence of irradiation on the catalase system (catalase, antecatalase and philocatalase) and on several oxidative enzymatic systems (oxidones and oxidases).

A metabolic change in the early periods after irradiation was reflected also in the change in the histamine content of the blood and other tissues.

The definite similarity between the radiation sickness syndrome and the phenomena of histamine shock, as well as the positive results obtained in the treatment of radiation sickness with antihistamine preparations, indicate the possible role of histamine in radiation sickness.

• Data of the workers listed were used in the paper: M. M. Gromakovskaya, S. Ya. Rapoport, G. V. Nizhnik, L. D. Lukyanovaya, S. R. Zubkovaya and E. I. Krivevskaya.

Using an improved method of detecting histamine, it was possible to show a significant increase in histamine content under the influence of irradiation. The maximum increase in histamine after the total irradiation of rats with a dose of 800 r was observed in the skin and stomach in 5 minutes, in the liver and kidneys in an hour.

The participation of nervous elements in the phenomena noted even in the early stages of radiation sickness, especially the clear disturbance of the histohematic barriers, was demonstrated by means of research which showed that the use of novocaine, atropine and morphine significantly decreased the disturbance of histohematic barriers, as well as other manifestations of radiation sickness.

The Institute of Biophysics of the Academy of Sciences
of the USSR.

A STUDY OF THE MECHANISM OF THE EARLY CHANGES IN THE PERMEABILITY OF HISTOHEMATIC BARRIERS UNDER THE INFLUENCE OF ROENTGEN RAYS

M. M. Gromakovskaya and S. Ya. Rapoport

It has been established by the authors of earlier work that a single total irradiation of animals with a lethal dose of roentgen rays precipitates the advance of changes in the permeability of histohematic barriers of the liver, muscles and brain.

With the aim of researching the mechanism of the phenomena established in the work mentioned, the significance of irradiation of different parts of the body was studied, as well as the role of the nervous system in the early changes in permeability of histohematic barriers in the presence of irradiation.

The work was conducted on rats. The irradiation was performed with a dose of 800 r using an RUP-1 apparatus; the strength of the dose was 31.4 r/min.; radioactive phosphorus, P^{32} , serving as an indicator of permeability, was put into the blood stream to give an activity of 4 μ c/ml.

The index of permeability used was the ratio of tissue radioactivity to the radioactivity of blood simultaneously taken, expressed in percent.

It was established that irradiation of the trunk alone, as well as irradiation of the entire animal, produces an increase in the permeability of the hematoencephalic barrier, whereas no changes were noted in the case of irradiation of the head or an extremity.

Irradiation of the trunk did not produce regular changes in the permeability of the liver barrier.

The role of the nervous system in the change in permeability induced by irradiation was studied by means of the prior injection of various neurotropic substances. By this means it was established that intraperitoneal or intravenous injection of 2 ml of 1% novocaine effects an increase in permeability of histohematic barriers in non-irradiated rats. Irradiation of the animal after the injection of novocaine does not alter the permeability of the histohematic barriers.

Intraperitoneal injection of rats with 1 ml of atropine (1:1000) decreases the permeability of histohematic barriers in nonirradiated animals. Irradiation of the atropinized animals does not produce any changes in the permeability of histohematic barriers.

Intraperitoneal injection of 0.5 ml of 2% morphine decreases the permeability of histohematic barriers

In nonirradiated rats. Irradiation of the animals after injection of morphine shows no effect on the permeability of histohematic barriers.

It was established that injection of novocaine, atropine or morphine prior to irradiation, as well as preventing a change in permeability of histohematic barriers, sharply decreases the affection of bone marrow.

The data obtained indicate the participation of a nervous mechanism both in the early shifting of the permeability of histohematic barriers and in the changes which affect the bone marrow. These data do not provide, however, sufficient basis for establishing a cause and effect relationship between the phenomena studied or explaining the intimate mechanism of the action of atropine, novocaine and morphine under irradiation. These questions require further research.

The Institute of Biophysics of the Academy of Sciences
of the USSR

THE INFLUENCE OF ROENTGEN RAYS ON THE HISTAMINE CONTENT OF TISSUES

E. I. Krichevskaya

The present work was undertaken with the aim of establishing the influence of a single irradiation with a lethal dose of roentgen rays on the histamine level of the blood and a number of organs differing according to radiosensitivity.

The research was conducted on white rats. Irradiation was effected with a three-tube x-ray unit; a dose of 800 r was employed at a strength of 500 r/min.

For the histamine determination a technique was worked out which made possible the extraction of histamine free from any contaminants and its quantitative determination with an accuracy of within 0.2 γ . The basis of the given method consisted in selective extraction with *n*-butyl alcohol in a strongly alkaline medium and subsequent separation by means of paper chromatography.

As a result of experiments conducted, it was established that in the early periods after irradiation (during the first hour) the histamine level in the skin, stomach, kidneys and liver is sharply increased.

In the later stages, before the actual death of the animal, there is observed, on the other hand, a lowering of the histamine level in all the above-mentioned organs.

The histamine content of the brain remains essentially unchanged under the influence of irradiation. The histamine content of the blood slowly increases under the influence of a single lethal dose of roentgen rays. However, a significant accumulation of histamine in the blood prior to the death of the animal was not observed even on the third day.

The Institute of Biophysics of the Academy of Sciences
of the USSR

THE PERMEABILITY OF THE BLOOD VESSELS OF THE PERITONEUM AND THE SYNOVIAL MEMBRANE IN RADIATION SICKNESS

S. B. Balmukhanov, A. G. Sérgazin, T. K. Kazangalova

The degree of disturbance of the permeability of the vessels in rabbits was studied at different periods after their irradiation with a 450 r. dose of roentgen rays. The permeability of the vessels was analyzed with the use of tracer doses of the radioactive isotope of phosphorus, P^{32} , and the radioactive isotope of calcium, Ca^{45} . Experimental data showed that the degree of permeability is determined by the gravity of radiation sickness. It was established that the effect of membrane-sealing preparations proceeds more sharply against a background of vessel permeability.

The V. M. Molotov Kazakhstan Medical Institute

THE FUNCTIONAL STATE OF THE CUTANEOUS VESSELS AFTER THE TOTAL IRRADIATION OF DOGS WITH A LETHAL DOSE OF ROENTGEN RAYS

V. V. Yakovlev

Up to the present time, neither the literature of this country nor the foreign literature has thrown any light on the question of the state of the cutaneous vessels following the action of ionizing radiation on the organism. In this connection, research was conducted in which the skin temperature, arterial tonicity and arterial pressure in the cutaneous vessels of a dog's ear were studied.

The methods used which made possible the study of these characteristics of peripheral blood circulation were skin thermometry, plethysmography and a method, worked out by the author, of determining the pressure in the vessels of a dog's ear.

After the action of roentgen rays on the animals, a significant increase in arterial tonicity was noted, which reached a maximum during the last days of the animals' lives. Skin temperature after irradiation fluctuated over a wide range, but the general tendency was a lowering, which reached a maximum during the last days of life. Arterial pressure in all of the animals decreased, the maximum decrease also being attained during the final days.

Experimental data obtained indicate that arterial pressure falls despite constriction of the cutaneous vessels. It is therefore possible to suppose that the changes taking place in the vessels of the internal organs have a decisive influence on the development of hypotonia in irradiated animals.

The Ministry of Public Health of the USSR

PHYSIOLOGICAL AND BIOCHEMICAL DATA ON THE NATURE OF PROLONGED HEMORRHAGE IN EXPERIMENTALLY INDUCED RADIATION SICKNESS OF THE ANIMAL ORGANISM

B. A. Kudryashov, G. V. Andreenko, P. D. Ulitina, G. G. Bazazyan, V. E. Pastorova,
N. P. Sytina, T. M. Kalishevskaya and E. E. Shimonaeve

In a number of research projects it has been asserted that in the circulating blood of an irradiated organism there appears a surplus of heparin, which inhibits blood clotting. The hemorrhagic state in radiation sickness has also been explained by some authors as the result of either an insufficiency of blood platelets or of hypoprothrombinemia. A study of the nature of the prolonged hemorrhage in radiation sickness was conducted by the authors on rats after their irradiation with roentgen rays or by injecting the animals with P^{32} .

Single doses of from 400 to 800 r. produced peritoneal hemorrhages in different organs from the eighth to the fifteenth day of the experiment. A similar phenomenon occurred after injection of P^{32} , 3-6 μ C per gram of body weight.

It was shown that the blood clotting time in the irradiated rats was retarded in comparison with that of nonirradiated rats. However, none of the signs of an increase in the level of heparin content of the blood were distinguished during the radiation sickness of the animals.

The concentration of prothombin, thrombotropin and fibrinogen remained at the physiological level in all stages of development of experimentally induced radiation sickness.

The Ac globulin content decreased on the average to 53% and was quickly restored to the physiological norm by the twelfth to thirteenth day of the experiment.

The disturbance of blood clotting was explained by a clearly evident deficiency of blood prothrombokinase and a concomitant falling off of the thromboplastic action of the blood.

The deficiency of prothrombokinase in the blood, caused by the irradiation of the animals, led to the organic formation of Factor VII in the serum. The content of Factor VII on the ninth and tenth day of the experiment fell on the average to 30%.

In the experimentally induced radiation sickness, the capillaries decreased in physiological stability to 34% of the norm, and this, together with the disturbance of blood clotting, created particularly favorable conditions for the appearance of hemorrhage.

Screening the upper lumbar region during irradiation with roentgen rays lowers the mortality rate of the animals and preserves to a comparatively large extent the thromboplastic activity of the blood. The authors explain these phenomena as the result of shielding the liver, and not the stomach or the spleen.

Vitamin B₁₂ and folic acid showed no medicinal effect on experimentally induced radiation sickness. A combination of "zonal shielding" and subsequent administering of vitamin B₁₂ and folic acid showed positive effects in preserving the thromboplastic activity of the blood on a physiological level.

A decrease in thromboplastic activity of the blood beyond a 30% limit leads to persistent hemorrhaging from wounds in the parenchymatous organs (the liver). A safe remedy in combating these hemorrhages is the local application of thrombin solution on fibrin foam. Other remedies had slight effect.

The M. V. Lomonosov Moscow State University

AN ANALYSIS OF THE EFFECT OF ROENTGEN IRRADIATION ON THE SECRETORY AND MOTOR FUNCTIONS OF A DOG'S STOMACH

A. V. Solovyev and O. V. Solodkina

The authors studied the influence of single general roentgen irradiation with doses of 400 and 500 r on the secretory and motor functions of the stomach in chronic experiments on dogs, on which prior operations had been performed using the method of A. V. Solovyev including the formation of two Pavlov's pouches— one on the lesser curvature of the stomach and the other on the greater curvature.

The operation was performed in such a way that the pouches received different innervations: The pouch from the lesser curvature preserved its connection with the vagus nerve; the pouch from the greater curvature was innervated mainly by a sympathetic nerve. This method was used in order to make possible an analysis of the nervous mechanism of the disturbances in stomach functions which occurred.

It was ascertained that the previously observed phases in the changes in secretory and motor functions of the pouches are oppositely determined in the small and large curvatures, i.e. they depend on the nature of the innervation of the pouches: a period of inhibition of secretion in the lesser curvature corresponds in time to a period of considerable secretory stimulation in the greater curvature and vice versa. Moreover, the inhibition in the lesser curvature was observed only during the first, complex reflex phase of secretion, while the second, the neurohumoral phase, remained within the limits of the norm. The increase in secretion in the greater curvature, on the other hand, took place for the most part at the expense of the second phase of secretion.

In this instance, if both pouches did not differ one from the other with respect to innervation, the differences noted above between the lesser and greater curvatures would not have occurred; the period of stimulation or inhibition of secretion would obtain for both pouches simultaneously.

Consequently, the difference between the pouches in their reaction to irradiation was determined first of all by the fact that they were supplied by different nerves.

This provides a basis for the supposition that the changes in the secretory function of the pouches which take place after irradiation are produced primarily by a disturbance of the normal interrelationship of the sympathetic and parasympathetic innervation of the stomach; moreover, the inhibition of the first phase of secretion is determined by a change in the functional state of the vagus nerve.

Following irradiation significant changes took place in the acidity of the gastric juice.

During the period of inhibition of the first secretory phase, the acidity of the gastric juice decreased on the average by twice the original amount. The acidity of the gastric juice of the second phase of secretion underwent a change dependent upon the original level: when it had been low before irradiation, it increased; when it had been high, it decreased.

A lack of correspondence was observed between the quantity of gastric juice and its acidity in the pouch from the greater curvature. During the renewal of secretion the acidity of the gastric juice was normalized.

The disturbance of the motor function of the pouches consisted, in the first place, in an inordinately high elevation of tonicity in the greater curvature after feeding, which often led to vomiting. In the second place, peristalsis increased in the lesser curvature, and decreased in the greater curvature.

In two cases the disturbance of the motor function in the greater curvature took a highly unique form: short periods (3 to 10 minutes) of almost complete rest alternated with periods of similar length of very intense constriction.

In the course of time (in 2 to 3 months) the motor function of the pouches, as well as the secretory, returned to normal.

The facts presented above make it possible to suppose that the changes on the part of the stomach following irradiation with the indicated doses are not linked with any serious organic injuries of the mucosa or

muscle layers; these changes are reversible, and are primarily caused, to all appearances, by the disturbance of the normal interrelationship between sympathetic and parasympathetic innervation of the stomach.

The I. P. Pavlov Institute of Physiology of the Academy of Sciences of the USSR

THE PATHOGENESIS OF ENDOCRINE DISTURBANCES RESULTING FROM RADIATION INJURIES

E. A. Moliseev

Up to the present, slight attention has been paid to the role of the pituitary among the physiological mechanisms in the pathogenesis of acute radiation syndrome. At the same time, a number of well studied phenomena of radiation sickness suggest the considerable participation of the pituitary (the anterior lobe in particular) in the development of radiation syndrome.

The present research was carried out on 43 mature male guinea pigs. The source of γ -radiation used was a GOP-1 cobalt unit; the exposures were single, with a duration of 3 to 4 hours. Correspondingly, the irradiation doses were fixed at 600 to 900 r.

Pituitary glands were taken for study only from those animals which became afflicted with radiation sickness and which were killed at different periods after irradiation (from one hour to a year and a half).

As a result of the experiments performed, the following conclusions can be drawn.

The anterior lobe of the pituitary in guinea pigs undergoes a sensitive reaction to a single, general irradiation with γ -rays.

In only two hours following irradiation, marked disturbances are noted which take the form of changes in the numerical relationship between chromophobes and chromophils in the anterior lobe of the pituitary.

During the first 4 to 5 days after irradiation, a significant increase in the number of alpha cells is noted. The number of basophils decreases in the same period of time, but undergoes in addition a definite fluctuation.

By the end of the first week after irradiation a decided change was noted in the tinctorial properties of the cytoplasm of the chromophill cells.

In the guinea pigs surviving long after experiencing acute radiation sickness, a lasting change was observed in the cellular composition of the anterior lobe of the pituitary, which took the form of a definite predominance of the small chromophobes. Also altered is the usual topographical distribution of different types of cells.

The changes encountered substantiate the position attesting to the participation of the anterior lobe of the pituitary in the pathogenesis of radiation sickness.

The I. M. Sechenov Institute of Evolutionary Physiology of the Academy of Sciences of the USSR

THE ROLE OF THE SUPRARENALS IN THE DEVELOPMENT OF RADIATION SICKNESS

A. V. Tonkikh

A number of researchers mention the participation of the suprarenal glands, the cortex in particular, in the reactions of an organism to the action of radiant energy. The bases for this assertion were morphological changes, changes in the content of cholesterol and ascorbic acid (which served as indicators of adrenal cortical activity), and also the fact that animals upon which adrenalectomies have been performed (rats and mice) are more sensitive to the action of radiant energy than intact animals. The data of different researchers, however, are not in agreement, even data which is cited in one and the same text; some of them mention an increase in adrenal cortical activity in the presence of irradiation; others, on the contrary, testify to a decrease in activity.

These contradictory data of different authors are apparently explained by the fact that they pertain to different periods after irradiation.

The author of the present work used the efficiency of the skeletal muscles as an indicator of adrenal cortical activity. In this way it was discovered that one of the consequences of the general action of roentgen rays on an organism is a change in cortical activity, which takes the form of an increase during the first days after irradiation and a sharp decrease on subsequent days, beginning with the seventh.

As was shown by experiments with the injection of adrenocorticotrophic hormone (ACTH) prior to irradiation and at different periods after irradiation, the changes in the activity of the adrenal cortex after irradiation cannot be explained by changes in the content of ACTH (the principal stimulant of the adrenal cortex) in the organism.

Here the direct influence of roentgen rays on the suprarenals in the case of general irradiation does not play a part (as some researchers propose); shielding the suprarenals with a lead plate during general irradiation did not alter the usual picture of the changes in adrenal cortical activity after irradiation.

The possibility is proposed of a direct reflex influence on the adrenal cortex resulting from irradiation.

Up to the present, the subject of the influence of radiant energy on the adrenal medulla has not been broached. This question requires study, especially taking into consideration the latest data (of Ilyin and Tonkikh) on the considerable role of the hormone of the medullary layer, epinephrine, in the regulation of blood circulation.

The I. P. Pavlov Institute of Physiology of the
Academy of Sciences of the USSR

THE QUESTION OF THE SIGNIFICANCE OF THE FUNCTIONAL STATE OF THE LIVER IN THE DEVELOPMENT AND COURSE OF RADIATION SICKNESS

M. F. Belovintseva and E. N. Speranskaya

Under conditions of varying pathogenic effects in humans and animals, the functional state of the liver occupies a place of exceptionally great importance in the reactions of the organism and the normalization of its internal environment. One and the same pathogenic factor, depending upon the ability of the liver to accomplish barrier, detoxication and other functions, produces different degrees of pathology in the organism.

The authors took upon themselves the task of explaining the significance of the functional state of the liver in the development and course of radiation sickness.

The observations were made on white mice and dogs in which the functional state of the liver was experimentally disturbed; then, after irradiation with roentgen rays, these animals were subjected to study.

The depression of the functional state of the liver was produced by means of surgical operations, as a result of which the route by which insulin enters the liver was changed, and the insulin supply of the liver parenchyma was decreased.

In previous research it had been shown that in animals operated on in this way the ability of the liver to store glycogen is depressed, the activity of liver tissue cholinesterase is lowered, and also the processes of regulation of the sugar level of peripheral blood are disturbed.

In the research conducted on white mice, the lowering of the functional state of the liver was effected by ligation of the pancreaticoduodenal vein.

In different series of these experiments it was observed that, as a result of general irradiation with doses of 500 and 800 r, the mice with the experimentally lowered function perished more rapidly than the controls. The latter were subjected to irradiation for the same periods as the experimental animals, but their pancreaticoduodenal veins were not ligated. A dose of 300 r did not cause the death of the mice in either the experimental or control group in the course of 30 days.

Observations were made of four dogs subjected to general irradiation with a double dose of 300 r or a single dose of 600 r.

Before and after irradiation of the dogs, a study was made of the following: 1) sugar curves of the peripheral blood as the result of a) administration of sucrose per os (14.0 g per kg of body weight), b) intravenous injection of glucose (0.4 g), c) intravenous injection of insulin (10.2 m.e. of insulin per kg of body weight); 2) the ability of the liver to accomplish parallel protective syntheses (the formation of sulfate esters before and after administration of hydroquinone was detected).

Experiments were conducted on two dogs in which the indicators listed above were studied for a control period and after the performance of the operation lowering the functional state of the liver; then the animals were subjected to general roentgen irradiation. The lowering of the functional state of the liver in the dogs was effected by an operation transplanting the opening of the pancreaticoduodenal vein (through which, in the main, the pancreatic hormones enter the liver) from the portal vein to the wall of the inferior vena cava. Two dogs remained intact and served as controls.

General, two-stage irradiation of a dog whose liver function had been depressed with a dose of 300 r induced significant disturbances of the sugar-regulating and protective functions of the liver. In the control animal the same doses of ionizing radiation did not effect changes of any particular significance in the sugar-regulating function, but the synthesis of sulfate esters was notably disturbed.

General, single-stage irradiation with a 600 r dose of the other dog with the altered liver function induced the development of acute radiation sickness syndrome and the death of the animal on the fourth day, whereas the same dose, administered to an animal whose liver remained intact, produced only a few disturbances in the sugar-regulating and synthetic functions of the liver.

The I. P. Pavlov Institute of Physiology of the
Academy of Sciences of the USSR

THE DISTURBANCE OF CORTICOVISCERAL INTERRELATIONS IN ACUTE RADIATION SICKNESS

I. T. Kurtsin

By means of experiments conducted on 50 dogs in which conditioned salivating reflexes had been induced and in which the functions of several internal organs were studied, it was established that, after total irradiation by roentgen rays with a dose of 150 to 250 r, both the functions of the cortex of the cerebral hemispheres and subcortical centers and the activity of the internal organs of the animals were distinctly disturbed. This was established by a group of authors in a simultaneous study of higher nervous activity and physiological functions of organisms. The duration of the disturbances varied from 2 to 3 months, and with the normalization of cortical activity the normal activity of the internal organs was restored. In clinically evident manifestations of radiation sickness, there was observed a functional weakening of the cortical cells and the prevalence in the cortex of the brain of an inhibiting process, which can either radiate into the subcortical centers and give rise to hypofunctional disturbances of the internal organs, or, as a positive induction, produce a strengthening of irritable processes and thus give rise to hyperfunctional disturbances of the internal organs.

The gravity of radiation sickness, as well as the character and extent of radiation affection of the cerebral cortex and internal organs, are conditioned not only by the extent of the action of penetrating radiation on the organism, but also by the type of nervous system and the functional state of the cortex prior to irradiation. The most acute radiation sickness occurs in animals with unbalanced types of higher nervous activity, either weak or unduly strong. In them also the corticovisceral disturbances are the most clearly marked. In dogs with experimentally induced nervous disorders, in the presence of a functionally weakened cerebral cortex, radiation sickness of a grave nature occurred, often resulting in death. Disturbances of higher nervous activity and the activity of their internal organs were more serious and of longer duration than in those cases in which the animals were subjected to the action of like doses of penetrating radiation in the presence of an initially normal cerebral cortex. The therapeutic use in these cases of a composite of medicinal substances (bromine, glucose, insulin, calcium chloride, vitamins K, C, B₁, B₆, B₁₂, nicotinic and folic acids) showed a favorable influence on the course of radiation sickness and decreased the extent of the disturbances of corticovisceral interrelations.

In the general composite of disturbances in corticovisceral interrelations in radiation sickness, the disturbance of afferent impulses from the internal organs is particularly significant. By means of experiments on 200 dogs and cats with organs isolated from the rest of the organism with respect to humoral relations, other authors have established a marked disturbance of blood pressure and respiratory reflexes from interoceptors of the spleen, lymph nodes, bone marrow, small intestine, liver and extremities.

In the pathogenesis of acute radiation sickness, together with the well-known role of humoral factors, of considerable, and perhaps determinative, significance is the disturbance of corticovisceral interrelations which appears under the action of penetrating radiation on the highly sensitive cells of the cerebral cortex and on the receptor apparatuses of the organism.

The I. P. Pavlov Institute of Physiology of the
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SOME DISTURBANCES OF HIGHER NERVOUS ACTIVITY IN RATS BORN FROM FEMALES IRRADIATED WITH IONIZING RADIATION DURING PREGNANCY

I. A. Plonkovsky, V. E. Miklashevsky and I. A. Bolodina

Under observation were 30 pregnant white rats, subjected to irradiation with γ -rays of radioactive cobalt in a dose of 200 to 250 r, at strengths of 8.3 units/min and 16.7 units/min, from the 11th to the 18th day of pregnancy.

Irradiation of the pregnant rats with γ -rays from radioactive cobalt in the dose indicated produced in them nonfatal attacks of radiation sickness. As a result of irradiation, the death of the embryos due to miscarriage was observed in some of the rats, but the majority of the animals were born at full term. Following birth some of the females lost the maternal instinct.

In 57 animals (35 experimental animals born of mothers subjected to the action of ionizing radiation during pregnancy, and 22 controls) higher nervous activity was studied with the use of the motor-protective technique and the motor-nutritive technique of Kotlyarevsky. Observations were made on the behavior of the animals in compartments, on the induction of positive and negative conditioned reflexes with respect to sound and positive conditioned reflexes with respect to light and on stereotypic tests were conducted applying techniques of external inhibition and alteration of conditions.

The research showed that higher nervous activity in rats born of mothers irradiated with γ -rays from radioactive cobalt during pregnancy in the majority of cases is characterized by a somewhat lowered efficiency of the cortical cells, weakened processes of internal inhibition (differentiating and extinguishing), decreased vitality of nervous processes, inertness and disturbance of equilibrium.

A property of the higher nervous activity of the rats subjected to experimentation was that the first of their processes to suffer was internal inhibition, phylogenetically the youngest. At the same time, often evident in the rats were lowered motor excitability, protracted preservation of the orientating reaction and the appearance of spontaneous aggressiveness.

The complex picture of the conduct of these rats was not only the product of the disturbance of cortical functions, but also the result of the disturbance of the interrelations between different levels of the cortex and between the cortex and subcortex. The weakening of the regulating influence of the cortex on the subcortex was significant, a fact which was evident in the behavior reactions of the animals.

According to type of higher nervous activity, the rats born of mothers irradiated during pregnancy with γ -rays from radioactive cobalt, in the majority of cases, could be classified as weak animals on the verge of sickness or already visibly sick with a nervous disorder.

The Institute of Higher Nervous Activity of the
Academy of Sciences of the USSR

THE QUESTION OF THE INFLUENCE OF IONIZING RADIATION ON ANIMALS WITH DIFFERENT TYPES OF NERVOUS SYSTEMS

L. I. Kotlyarevsky, L. S. Gorshelova and L. E. Khozak

Research on the changes in higher nervous activity produced by penetrating radiation in comparatively small doses (a single dose of 50 r administered once a week in a general, seven-part irradiation) showed that

the character and degree of gravity of these changes depend upon the typological properties of the nervous system in the animals (white rats).

Different variations in the reactions of the animals to the action of roentgen rays began to appear in the very first stages of experimentation.

Animals with a strong balanced type of nervous system, during the first days after each irradiation reacted by a depression of the irritable process and a weakening of active inhibition. The latter could be detected for the most part only in the first inhibitory phase of a vestigial conditioned reflex. In an extensive study of the postradiation period after three-stage, and particularly after seven-stage, irradiation, the disturbances of higher nervous activity assumed an undulating character. Full normalization of conditioned reflexes was observed only after three-stage irradiation.

Research on animals with an excitable type of nervous system showed that each session of irradiation produced in them a significant boost in the irritable process with a disturbance of stress interrelations of conditioned irritants, phase phenomena and a decided weakening of active inhibition with the predominance of the ultraparadoxical phase. It has often been observed that, against a background of reduction and subsidence of existing, positive conditioned reflexes, the vestigial conditioned reflex is fully normalized.

Normalization of conditioned reflexes in these animals was not observed during the one-hundred day study of the postradiation period. Motor excitation predominated in their general behavior pattern.

At each session of irradiation, animals with a weak type of nervous system reacted by a gradual lowering of the excitability of the gray matter. As a result of a weakening of basic nervous processes, manifestations of a decided exhaustibility of the gray matter were not infrequently noted, along with the disturbance of natural conditioned reflexes. The general behavior of these animals, particularly after seven-stage irradiation, was pre-eminently characterized by depression and immobility.

Both in the case of normal higher nervous activity in the presence of the action of roentgen rays, and under the influence of diphtherial or staphylococcal infection in animals previously subjected to irradiation, the pathological process took place with significantly greater gravity and duration in animals with a weak type of nervous system. The point is that in these animals the cells of the cerebral cortex, which differed from normal by a lowered limit of efficiency, as a result of the action of roentgen rays were weakened still more, and against this unfavorable background, experimentally produced bacterial infection obviously caused significantly graver disturbances than in control animals also belonging to the weak type.

Among animals of the strong, balanced type, the picture of the advance and recession of disturbances of higher nervous activity produced both by irradiation and by subsequent infection is much lighter and more rapid than among animals of the weak type, a fact which, in all probability, results from the greater functional capacity and resistance of the cerebral cortical cells of these animals to every type of harmful influence.

In contrast to representatives of the strong, balanced type of nervous system, with respect to the gravity of disturbances of higher nervous activity, animals of the excitable type are closer to animals of the weak type, a fact which can be explained by the weakness and inadequacy of internal active inhibition in the cerebral cortex of these animals.

The Institute of Higher Nervous Activity of the
Academy of Sciences of the USSR

MORPHOLOGICAL CHANGES IN THE CEREBRUM AND INTERNAL ORGANS OF ANIMALS AS A RESULT OF GENERAL IRRADIATION

M. M. Aleksandrovskaya

A joint physiological and morphological study conducted by the author of the mechanism of the action of ionizing radiation in small doses of roentgen rays on the central nervous system (single dose of 50 r and total doses of 100, 150, 250, and 350 r) affords grounds for assuming that there exists not only an environmental effect on the nervous cells of the brain via the blood vessels, but also a direct effect of radiant energy on the parenchyma of the brain. The latter supposition is based on the fact that vascular changes resulting from the indicated doses were significantly less marked than changes in the nerve cells.

A morphological analysis of changes in the central nervous system in the internal organs of animals subjected to repeated irradiation with small doses of roentgen rays (an overall dose of 250 and 350 r) with subsequent infection by staphylococcus and diphtheria toxins, against a background of incomplete rehabilitation of conditioned reflexes, showed significantly more marked dystrophic changes in the central nervous system among experimental animals than among control animals subjected to the action only of roentgen rays or only of the toxins. In the presence of radiation sickness, intoxication and infection processes proceed in an unusual manner. Along with this, the nonreactivity of the microglia characteristic for small doses of roentgen rays is replaced by a unique type of reactivity. This singularity consists in a marked proliferation of mesenchymal cells in the brain and spinal cord and, in addition, unusual nuclear reactions of the microglia in the white matter.

A histological analysis of rats conducted after general single irradiation with γ -rays in doses of 650 and 1300 r and repeated irradiation with a total dose of 1850 and 2950 r, makes it possible to characterize the pathological process in the brain as hypoxic encephalopathy. The character of the morphological changes attached to these doses remains general, differing only in degree of intensity of the changes.

The existing opinion of the insensitivity of elements of connective tissue, fibrous structures, and intercellular material, as well as of the neuroglia, is not corroborated by the data of the research. On the contrary, the tissues indicated do not remain invariable: substantial disturbances occur in the ectodermal and mesodermal elements of the brain and spinal cord. As a result of single and repeated irradiations with comparatively small doses of roentgen rays (from 50 to 350 r), there was noted in the microglia a decrease in proliferating reactions, an atrophic type of change. At the same time ectodermal elements of the neuroglia, astrocytes and the oligodendroglia were altered by increased proliferation.

The nonreactivity of the microglia characteristic of small doses is replaced by a unique reactivity of the neuroglia in animals subjected to the action of ionizing radiation in the presence of intoxication and infection. With respect to the effects of large doses of γ -rays from Co^{60} , from 650 to 2950 r, in making an overall characterization of the reactions of the microglia, one should note the productive-dystrophic nature of its changes in structurally different tissue formations in the brain and spinal cord.

The facts gathered attest to a depression of oxidizing processes in the tissues of the brain and spinal cord after the exposure of animal organisms to ionizing radiation. The data adduced are finding confirmation in current experimentation, which is expressed morphologically in metabolic and hypoxic changes.

A comparison of physiopathological and morphological changes in the central nervous system showed that, as a result of different doses of ionizing radiation, among animals with the gravest disturbances of higher nervous activity, morphologically there were observed the greatest destructive changes in the brain, spinal cord and internal organs.

The Institute of Higher Nervous Activity of the
Academy of Sciences of the USSR

THE ROLE OF THE NERVOUS SYSTEM IN RADIATION SICKNESS

P. F. Minaev

On the basis of experimental data the author formulated the hypothesis that the central nervous system, and particularly its highest division—the cortex of the cerebral hemispheres—possesses unusually high sensitivity (reactivity) to penetrating radiation but, at the same time, considerable stability (resistance) toward it.

The sensitivity and stability of the nervous system toward penetrating radiation and, apparently, toward all irritants of the external environment are two mutually complementing characteristics of its activity, normally and pathologically.

Metabolic processes are the basis of the sensitivity and stability of the nervous system. The sensitivity of the nervous system in a certain measure depends upon the oxidizing mechanism of the utilization of carbohydrates by nervous tissue, whereas the resistance of the nervous system depends to some degree on the stability of nucleic and amino acids and also on the stability of the glycolytic mechanism of the utilization of carbohydrates by nervous tissue.

As a result of the action of penetrating radiation on the brain and spinal cord, there occurs a disturbance in the harmony of these aspects of the activity of the nervous system, and this leads to functional changes in the organism. These changes are detected in comparatively mild form in bone marrow and peripheral blood.

Local irradiation of the cerebral hemispheres and cerebellum with doses of 7000 to 9000 r and total irradiation with a dose of 1000 r result in suppression of mitosis of the cells of the bone marrow and damage to single anuclear erythrocytes in the bone marrow and peripheral blood (in birds).

In the case of irradiation of the cerebral hemispheres, leucocytosis was observed in the peripheral blood while irradiation of the cerebellum resulted in leucopenia.

In animals with cerebral hemispheres removed or with cerebella removed, the development of radiation sickness is not identical; in the first group prolonged leucopenia was observed in the peripheral blood, while among the second group leucopenia was practically absent.

In animals without cerebella resistance to ionizing radiation was increased.

The Institute of Biophysics of the Academy
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THE ROLE OF DIRECT AND REMOTE EFFECTS OF IONIZING RADIATION

E. Ya. Graevsky, N. F. Barakina, Z. N. Faleeva, and I. M. Shapiro

A comparison of the direct and remote influence of radiation was made using white mice in three basic types of experiments: 1) general irradiation of the animal, 2) local irradiation of an organ or system being studied and 3) shielding of the organ or system being studied during irradiation of the remaining parts of the body. Quantitatively analyzed were the changes occurring in bone marrow, spleen and peripheral blood, the mitotic activity of corneal epithelium and the influence of irradiation of mother and embryo on the process of intrauterine development.

Changes in the hematopoietic organs provide the basis for assuming that the destructive processes observed in them are determined principally by the direct action of radiation. Remote effects did not tell appreciably on either the irradiated or nonirradiated parts of the hematopoietic system. The sanative influence of the non-

irradiated parts of the organism was expressed in a marked strengthening of restorative processes in the hematopoietic organs and depends, apparently, on the preservation within the organism of centers of hematopoiesis, however small, rather than on the size of the screened portion of the body.

In the case of local irradiation of the hind extremity, spleen or small intestine, substantial deviations from the norm were not observed in the peripheral blood. At the same time, when any of these organs were shielded and the rest of the body irradiated, changes typical of general irradiation occurred in the cellular composition of the blood. Probably the changes in peripheral blood in radiation sickness result from the attack on the entire hematopoietic system or a significant part of it.

Both in the case of general irradiation of the animals and in the case of local irradiation of the eyes, within six hours after irradiation the number of mitoses in the corneal epithelium fell to zero. Toward the end of the first day mitosis recommenced, but even on the fifth day remained significantly less than normal. In these two series of experiments, there were observed as a rule, beginning 24 hours after irradiation, pathological forms of mitosis. When the head was shielded, and also when a supplementary shield was used for the supranal or lumbosacral areas, the falling off of mitotic activity began only 24 hours after irradiation and remained on a lowered level for three days; then the proper number of mitoses was reestablished. Pathological mitoses were not encountered in these cases. Characteristic of the direct action of radiation are: the cessation of mitotic activity during the first hours after irradiation, the appearance of pathological forms of cell division and the slow restoration of mitotic activity. A later and less severe depression of mitotic activity and the absence of pathological forms of mitosis are peculiar to the reflected influence of radiation.

A study was made of the influence of irradiation of females in the sixth and ninth days of pregnancy on the development of irradiated and nonirradiated embryos. On the 17th and 18th days of pregnancy a determination was made of the number of living and dead embryos and their weight. The direct irradiation of embryos produced a sharp decrease in their weight and viability. Irradiation of the mother did not affect the development of either the irradiated or nonirradiated embryo. Consequently, the affection of embryos resulting from general irradiation on the sixth and ninth days of pregnancy is determined by the direct action of radiation.

The material presented permits the supposition that the fundamental destructive phenomena which appear in radiation sickness are the result of the direct influence of radiation on the corresponding organs or system. The remote effects of radiation can affect only certain aspects of cellular and organic metabolism and in a number of cases can not at all affect the direct effects of radiation.

The favorable influence of nonirradiated tissues on irradiated tissues can have a significant degree of specificity. The regeneration of a system damaged by radiation can be accelerated first of all by the presence in the organism of intact cellular elements of the same system.

It is possible that the shielding of separate organs or systems during irradiation of an organism, while decreasing affection generally, will facilitate the restoration of systems damaged by the radiation.

The A. N. Severtsov Institute of Animal Morphology
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THE DISTRIBUTION OF INTRAVENOUSLY INJECTED STAINS IN THE TISSUES
OF NORMAL MICE AND OF MICE IRRADIATED WITH ROENTGEN RAYS

L. I. Korchak

In the appearance and development of radiation reactions of an organism, considerable significance is attached to the disturbances in tissue permeability resulting from the action of ionizing radiation. The

Increase in permeability of the vessels of the intestinal wall and other tissues is regarded as one of the characteristic and essential signs of radiation sickness, promoting the diffusion of toxins and bacteria. However, the fact that substances lowering permeability do not exert a protective influence on the irradiated animals hardly indicates that tissue permeability determines the development of radiation reactions. It can be supposed that the changes in the distribution of substances entering the organism after irradiation are, to a certain extent, linked with a change in the adsorptive properties of protoplasm.

Experiments were conducted on white mice six to eight weeks old, weighing 18 to 20 g. The animals were exposed to a single general irradiation with roentgen rays in doses of 400, 700 and 5000 r.

The work included a study of the distribution of neutral red and methylene blue stains injected intravenously into the animals at different times after irradiation. The amount of neutral red injected was 1.5 mg per mouse, of methylene blue - 0.8 mg per mouse. Sixty minutes after the injection of the stains the animals were decapitated, stain was separated from the tissue with acidified alcohol, and the extractions were subjected to colorimetry.

The data obtained attest that increased accumulation of stain following exposure to radiation in all doses is detected chiefly in the small intestine and spleen.

Experiments conducted with the stained tissues removed from the organism at different times after irradiation showed that the accumulation of stain is linked with changes in the condition of the tissues. These changes were deflected to a significant extent, inasmuch as they did not develop in the surviving tissues.

The increase in tinctorial properties produced by general exposure to ionizing radiation is linked not so much with a disturbance of vascular permeability as with changes in the ability of the tissues to adsorb stain. The coincidence of the time of maximum accumulation of stain with the period of the most marked destructive processes argues in favor of the notion that increased accumulation of stains by the radiosensitive organs of the irradiated mice is linked with the processes of disintegration taking place within them.

It can be supposed that many phenomena described in the literature, which are connected with a disturbance in permeability under the influence of irradiation, may in reality be determined to a significant extent by a change in the adsorptive properties of the same tissues.

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THE QUANTITATIVE CHARACTER OF REPARATIVE PROCESSES TAKING PLACE IN AN ORGANISM AFTER GENERAL IRRADIATION

E. I. Tolkacheva

At different periods after the total irradiation of mice with roentgen rays in a dose of 250 r, changes were observed in the reactivity of the animals to a second exposure to the action of roentgen rays. These changes were of a phase nature and were the result of destructive and reparative processes going on in the irradiated organism.

During the first two days after total irradiation of the animals with a dose of 250 r, there was observed in them a heightened radiosensitivity, which was demonstrated by a second exposure. It was obvious that in this period of time there had taken place in the irradiated organism a very advanced development of destructive changes, uncompensated for by reparative processes. During the period from the fourth to the seventh day after irradiation, the normalization of the radiosensitivity of the animals was observed, a fact which indicates the rapid rate of the reparative processes going on within them.

On the 14th day after irradiation with a 250 r dose, there was observed in the animals a tendency toward hyperirradioreistance, which decreased in the latter periods of observation (on the 21st and 28th days after irradiation).

The change in form of the mortality curve as well as the distribution in time after irradiation of the deaths of the animals can serve as good quantitative indicators of reparative processes.

The quantitative character and periodicity of the changes in radiosensitivity of animals after irradiation depends upon the dose of radiation employed.

The Institute of Biophysics of the Academy
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THE ROLE OF THE SUPERIOR CERVICAL SYMPATHETIC GANGLIA IN REACTIONS TO PENETRATING RADIATION OF CONTROL RATS AND RATS ACCLIMATIZED TO HYPOXIA

Z. I. Barbashova

A study of the role of the autonomic nervous system, the sympathetic system in particular, in the mechanism of an attack of radiation sickness is a matter of considerable interest. In the present work are presented the results of research on the role of the superior cervical sympathetic ganglia and cervical nerves in the reactions of white rats to γ -radiation, the source of which was Co^{60} with a radiation strength of 3.1 r per minute.

The removal of the superior cervical sympathetic ganglia and cervical sympathetic nerves lowered the resistance of the white rats to subsequent action of ionizing radiation. This was manifested in a graver course of radiation sickness, a higher mortality rate, earlier disturbances of hematopoiesis and more severe affection of the vascular system, and, finally, a more marked change in the process of exchange of gases among the surgically altered rats than among control animals subjected to equal doses of irradiation.

The resistance of the rats upon which ganglionectomies had been performed could be increased by adapting them to oxygen hunger (by keeping them in a pressure chamber at an "altitude" of 7600 meters for four hours daily over a period of one month).

Among the rats upon which ganglionectomies had been performed and which were later acclimated to hypoxia, there was observed a lowered mortality rate, a less marked fall in body weight, less severe and later-appearing changes in blood composition and greater stability of metabolic processes after the action on them of like doses of γ -radiation, in comparison with animals upon which ganglionectomies had been performed, but which had not been acclimated to hypoxia. In some cases their reaction to ionizing radiation was even less marked than among intact control animals. Thus, in the presence of a definitely lethal dose of 1200 r, from which perished not only the animals upon which ganglionectomies had been performed, but all the controls as well, certain individual in the group of rats upon which ganglionectomies had been performed and which were also acclimated to hypoxia were stricken with relatively mild radiation sickness and did not die.

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THE KINESIS OF RADIOCHEMICAL TRANSFORMATION IN THE BIOSUBSTRATE AND THE PROPHYLACTIC EFFECT

B. N. Tarusov

A kinetic analysis of the regularities of radiation sickness shows that death occurs, both in higher and lower organisms, as a result of the development of chemical reactions. The biological effect is determined by the conditions of the evolution of aftereffect reactions in the course of time. In the formulas of the target theory describing the regularity of mortality and survival, the absence of the factor of time is without foundation.

As a result of kinetic research conducted by a number of authors on different objects, it has been established that the aftereffect of radiation is made up of two successive reactions: a) a reaction with an initially high rate evolving according to type a^{-x} (a reaction involving unbranched chains), and b) a reaction evolving in time according to type a^{-x} with a significant induction period (clearly a chain reaction involving branched chains).

The probability of death of an organism from the first reaction in the presence of lethal doses rises proportionately with an increase in the dose. The probability of death as a result of the development of the second, autocatalytic reaction is inversely proportional to the dose.

The path of the survival curves (the Poisson equation is $\frac{(DP)^k}{k!} 1 - DP$) is determined, not by the number of hypothetical shocks to the sensitive center, but by the probability of the development of a chain reaction (which determines the extent of affection) of an approximately definite length. The exponent k describes the number of ramifications in the elementary sections of the reaction.

In the case of death from the first reaction (in the presence of large doses) the survival curves are exponential in dependence on the dose; in the case of death from the second reaction they have an S-shaped character. The substrate of this second reaction is the lipids of the cells. Prophylactic agents serve as inhibitors of this autocatalytic reaction of the aftereffect of radiation in the lipids.

There was observed a full correlation between the inhibiting effect on the chain oxidation reactions produced by irradiation of, in sum total, the lipids of the liver and the prophylactic effect.

A fact arguing in favor of the action of prophylactic agents on the chain reaction in the lipids is the existence of a clear upper and lower limit in the presence of changes in oxygen pressure (the oxygen prophylactic effect) both in the lipids and in the survival and mortality curves of organisms.

Data were obtained showing that a qualitative difference does not exist in the action of prophylactic agents at different periods of time during the origin and development of the aftereffect reaction. The grounds for drawing such a conclusion is the fact that the reactivity of the inhibitors (the prophylactic agents) falls off sharply in time with the development of the reaction.

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THE HEMOTOXIC FACTOR IN THE TISSUES OF ANIMALS SUBJECTED TO THE ACTION OF IONIZING RADIATION

S. A. Korol and M. R. Mednik

It is well known that under the influence of ionizing radiation toxins make their appearance in animals, not only in the blood, but also in the tissues. The problem of the hemotoxic factor in the tissues of irradiated

animals, however, has been insufficiently illuminated in the literature, a fact which served as the basis for carrying out the present work.

The objects of the research were the different tissues of rabbits, rats and mice killed by the action of ionizing radiation (roentgen rays and β -radiation from the radioactive isotope of phosphorus) or, in accordance with the conditions of the experiment, put to death as required.

The rabbits were irradiated with a dose of 1000 r, the rats with a dose of 750 r and the mice with a 900 r dose. Radioactive phosphorus was used only for the rabbits in doses of 1.5, 3.0, and 5.0 mC. Saline solution and alcohol extracts of entire tissues were studied, as well as their nuclear substance.

Hemotoxins were detected in the extracts of the tissues of the irradiated animals (rabbits, rats and mice); the hemotoxic factor of greatest strength was noted in liver extracts.

The effect of hemotoxic action was detected in the saline solution and alcohol extracts, to a greater extent in the latter, a fact which attests to their lipoprotein nature.

The results of the experiments conducted showed that the hemotoxic factor does not possess a marked degree of specificity. Hemotoxins were detected to a greater extent in the extracts of whole liver tissue than in the nuclear substance. The strength of the hemotoxic effects increases proportionately with the development of radiation sickness.

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VITAL OBSERVATION OF THE DISTURBANCES OF OXIDIZING PROCESSES IN THE CENTRAL NERVOUS SYSTEM

A. D. Snezhko

The task was undertaken in the present research of determining the oxygen balance in the brain under the influence of partial and total irradiation in a protracted experiment.

The oxygen disturbance in the brain was determined in the experiment by means of polarography, with the use of a technique called "the oxygen test".

A comparison was made of hemodynamic changes and oxygen disturbances in the brain as a result of the action of ionizing radiation. The data obtained permit the assumption that changes in the pressure of O_2 as a result of irradiation are produced by a disturbance of the respiratory function of a tissue.

The experiments showed that the action of ionizing radiation almost immediately produces a change in the oxygen pressure of the brain, specific for different localizations of irradiation.

In the case of total irradiation of the whole head and small portions of the brain, i.e., in the case of a direct effect on the brain, an increase in oxygen pressure in the brain was noted. In the case of irradiation of the abdominal area oxygen pressure decreased.

Repeated irradiations with different localizations of irradiation produced pressure changes characteristic of the given localization. In other words, prior irradiation did not exert any influence on the results of a second irradiation if the localization was not the same; for example, after primary irradiation of the head, secondary irradiation of the abdominal region produced a typical reaction—the lowering of oxygen pressure.

In some cases of radiation sickness a change in the lability of oxidation processes was clearly marked in the form of a change in the configuration of the pressure curve.

The polarographic determination of oxygen pressure with continuous photorecording permitted the detection of rhythmic fluctuations of the basic level of oxygen pressure with their specific localization in the brain structures.

There were noted basically two types of fluctuations: one at a rate of 10 to 15 per minute and another at 2 to 3 per minute. As a result of the action of ionizing radiation, the rhythmic fluctuations in the basic pressure level underwent regular changes, specific for different localizations of the action. Certain parallels were established between the reaction of an animal to irradiation observed during the first hours after irradiation and the change in the rhythmic fluctuations of the basic level of oxygen pressure.

The Institute of Biophysics of the Academy
of Sciences of the USSR

EXTRA-SLOW RHYTHMS IN THE CHANGES IN ELECTRIC POTENTIAL OF THE CEREBRAL CORTEX AND HYPOTHALAMUS IN RADIATION SICKNESS

N. A. Aladzhazlova

In the cerebral cortex and in some subcortical structures of the rabbit and the cat extra-slow rhythmic fluctuations can be recorded in potential, the period of which is considerably greater than that of the "slow waves" recorded in an electroencephalogram.

Two fundamental extra-slow rhythms were established: one of 8 to 9 oscillations per minute with an amplitude of 0.2 to 0.7 millivolts and another of 0.5 to 2 oscillations per minute with an amplitude of 1 to 1.5 millivolts. The parameters of the extra-slow rhythms are changed as a result of a number of actions on the central nervous system.

After roentgen irradiation of a rabbit the parameters of the extra-slow rhythmic fluctuations in potential of cerebral cortex and subcortex underwent changes dependent upon the dose and localization of the action. Irradiation of the head with doses of 300 to 2000 r led to a depression of the rhythms for a few hours after irradiation and to an increase in their amplitude by 5 to 10 times during the next few days. Irradiation of the abdominal region with the same doses, while the rest of the trunk and the head were screened, produced immediately after irradiation an intensification of the extra-slow fluctuations, as a result of which the frequency increased for a few days from 7 to 8 oscillations per minute to 10 to 12 oscillations per minute. Total irradiation with relatively small doses (100 r) led to an increase in the extra-slow rhythms.

Large doses, 3000 to 5000 r for local exposure and 1000 r in total exposure, led to other regularities in changes in the extra-slow fluctuations in potential of the cerebral cortex.

The changes in the parameters of the extra-slow rhythms were contrasted with the physicochemical and functional state of the cerebral cortex. For this purpose, in protracted experiments, a study was made of the electroconductive properties of the cerebral cortex at a frequency of 10,000 cps (impedance) and the electrical reaction of the visuosensory cortex on illumination of the eye with a light flashing 8 times per second.

A few phases were observed in the change in impedance of the cortex of the cerebral hemispheres and in the change in the electrical reaction of the visuosensory cortex on illuminating the eye after irradiation. These phases were, in general outline, analogous for irradiation both of the head and of the abdominal region.

In the early stages after irradiation there occurred a falling off of impedance and a disturbance in transforming the rhythm of illumination in the visuosensory cortex. An analysis indicated a decreased excitability of the cerebral cortex and the presence of physicochemical changes in the substrate surrounding the nerve cells of the cerebral cortex (in the neuroglia).

In the rabbit hypothalamus, in the early stages after both local and total exposure, there appeared extra-slow waves with a duration of approximately 8 seconds and an amplitude of approximately 3 millivolts. These fluctuations differed in form from the extra-slow rhythms in the cerebral cortex, but agreed in frequency.

The work included a consideration of the role of the reflex and toxic factors in radiation sickness, the direct effect of radiation on structures of the cerebrum, and the influence of changes in the regulating function of autonomic centers on metabolic changes in the cerebral cortex.

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of Sciences of the USSR

THE QUESTION OF THE SPECIFIC EFFECT OF PENETRATING RADIATION ON AN ORGANISM

E. I. Bakin

On the basis of the results of experiments performed both on isolated organs and tissues (a nervous-muscular preparation) and on the whole organism (cold-blooded and warm-blooded animals), it can be considered that the reaction of an organism to the action of penetrating radiation has both features which are nonspecific, analogous to harmful agents of a different nature, and features which are unique and specific and which serve to distinguish this agent from all harmful agents of the external environment. The specific features of the reaction of an organism to irradiation are chiefly related to the following:

1. With respect to its action on an organism, penetrating radiation is only a harmful agent in almost all ranges of dose and strength, i.e., it only injures, without producing waves of excitation at the same time.
2. The irreversibility of the injury is a specific feature of the effect of penetrating radiation on an organism.
3. The absence of an accommodation (adaptation) parameter in the presence of continuous and protracted irradiation treatment of an organism with any small dose.
4. The chief role in the injurious effect is played, not by the strength or size of the dose, but by the length of time of continuous irradiation, i.e., the duration of the action is a specific feature of the harmful effects of the rays.
5. The presence of a considerable latent period, which extends for days, weeks and longer, particularly in the case of small doses.
6. The absence of a marked reaction of protective significance (shock or a checking mechanism).
7. The presence of a specific, direct, reflexotropic susceptibility to injury.
8. The presence of specific forms of a functional state (the so-called radium spasmodic and tonic states) and other specific reactions of an organism.

The author considers that in the light of these data there emerges a very essential question to which attention must be paid. In his opinion the natural sources of radiation found in the animal organism (K^{40} , C^{14} , H^3 and others) take an intimate part in the automatism of vital functions and other manifestations of life and, consequently, are, as it were, among the participating stimuli of the vital processes.

But, according to the experimental data presented above, penetrating radiation is only a harmful agent.

Consequently, the author observes, there clearly emerges something of a contradiction: on the one hand penetrating radiation in the natural state of an organism is a stimulus to the vital processes and participates,

according to many data, in the automatic activity of living systems; on the other hand it is a particularly harmful agent in small doses. The author draws the conclusion that these natural sources of radiation found in the organism participate, to all appearances, not only in the vital processes as a stimulus (a false stimulus) but also in the gradual chronic injury to the different structures which include these functions; i.e., it is possible that in the very process of growing old, along with external cosmic and terrestrial radiation, a part is played by these natural sources of radiation found within the organism, without which, apparently, life itself is unthinkable. (It is well known that at a young age these natural sources are present in greater abundance).

Therefore one can fully apply to penetrating radiation the appellation "rays of life, aging and death", which, in the natural state of the organism, stimulate definite life processes and at the same time irreversibly injure the living system, which, while being irreversibly altered, "grows old" and dies.

The Kirgiz State Medical Institute

CYTOCHEMICAL CHANGES IN THE CENTRAL NERVOUS SYSTEM AS A RESULT OF THE ACTION OF IONIZING RADIATION

A. L. Shabadash

In the majority of published morphological studies it is asserted that the nervous system is radioresistant within dosage limits of 50 to 100 r; vacuolation and necrosis of nerve cells are reported resulting from larger doses. Attempts at a reliable neurohistological analysis have been presented in a number of separate studies in the last few years.

A histochemical technique has been worked out by the author by which he has detected nucleoproteins and their spatial distribution in nervous tissue; it is based on the calculation of the differences in the isoelectric points of proteins and sheds light on subtle physicochemical changes in structural details in the processes of vital activity.

In addition to making more precise the already well-known localization of ribonucleic proteins (RNP) in the nucleolus and tigroid masses of the nerve cell, we succeeded in detecting RNP in the mitochondria and in showing that the biological state of the nerve cell is clearly reflected in form and chemical activity of the mitochondria.

General irradiation of animals with roentgen rays in doses of 25 to 100 r caused a shift in the isoelectric points of the nucleoproteins of 0.3 to 0.4 units to the acid side of the pH scale. The reason for the change, apparently, are processes of depolymerization and/or a decrease in the quantity of nitrogenous bases. Histochemical changes were not uniformly manifested in different sections of the nervous system and were not qualitatively identical. The reactions of the mitochondria, detected significantly earlier than the qualitative changes in tigroid and particularly affected sections of the central nervous system, led to evident injuries.

The diencephalon of the brain and the reticular substance are, in the opinion of the author, "the front line" of reactivity in relation to ionizing radiation. The vast quantity of variegated mitochondria characteristic of them undergoes (due to neural damage, gliosis etc.) a progressive, wave-like diminution of ribonucleic proteins; the quantity of the intact organelles is sharply decreased, while the quantity of those pathologically altered increases significantly. These processes attest to local metabolic disturbances of, in the first place, respiratory exchange, oxidative phosphorylation and the citric acid of the Krebs cycle.

The detected histochemical signs of radiobiological reactions in the diencephalon and reticular substance correlate with many pathological manifestations (for example, intestinal and general dystrophy, disturbances in temperature regulation, etc.), characteristic of different injuries to these regions.

In contrast to the usual pathohistological data, a histochemical study (of nucleoproteins in particular) reveals early, subtle and dynamic signs of the reactivity of the nervous system, on the basis of which are possible, not only a clarification of the separate aspects of the reaction mechanism, but also attempts at interfering with the outcome of the processes.

The Institute of Biophysics of the Academy
of Sciences of the USSR

HISTOCHEMICAL RESEARCH ON THE NUCLEIC ACID CONTENT OF THE TISSUES OF IRRADIATED ANIMALS

N. N. Kurshakova

In spite of the appearance of much research work on the influence of radiant energy on the animal organism, up to the present little study has been made of the disturbances arising in metabolic processes, of the nucleins in particular. The information on this question to be found in the literature does not give a sufficiently full presentation of the disturbances in nucleic acid content resulting from the action of ionizing radiation.

In connection with this it was interesting, employing histochemical techniques, to study the content of nucleic acids, after roentgen-ray action on an organism, in certain tissues possessing different radiosensitivities, and the influence of the direct and indirect effects of radiation on these compounds.

With this aim experiments were performed with single general irradiation of animals with a dose of 650 r, irradiation of the upper abdominal region with a dose of 4100 r, of the lower abdominal region with a dose of 2500 r and irradiation of the head with a dose of 1700 r. A study was made of the content of ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) in the lymph nodes, duodenum, liver, cerebral cortex and spinal cord in irradiated and control animals. It was shown that, in the case of single general irradiation of animals with definitely lethal doses of roentgen rays, changes in nucleic acid content are observed in the lymph nodes, duodenum, liver, cerebrum and spinal cord. In all of the organs studied these changes did not prove to be of the same type with respect to the nature and degree of their expression. The most marked changes in nucleic acid content were noted in the lymph nodes, duodenum and liver. They were less evident in the cerebrum and spinal cord.

The changes in nucleic acid content which were observed in different tissues of the irradiated animals proved not to be of the same nature. In the lymph nodes the action of roentgen rays in the early stages led to a significant (in comparison with a control) increase in the content of DNA and RNA, but in the latter stages to a decrease. The nucleic acid content of the duodenum at all periods after irradiation was lowered in comparison with that of a control. In the liver the content of RNA and DNA changed equivocally. At the same time that the content of RNA in the liver cells increased during the first hours after irradiation as well as in the latter periods, the quantity of DNA was lowered. With respect to the ambiguity of changes in RNA content taking place in separate nerve cells, it was possible to note a decreased content in the spinal cord and an increase in RNA content in the cerebral cortex.

The research, which included irradiation of the body of an animal (the head and upper and lower abdominal regions), showed that a change in nucleic acid content in the organs examined is observed in all the methods studied of afflicting an organism with roentgen rays. These changes were more evident, however, in the case of direct irradiation of the organ being studied and were less substantial as a result of the indirect action of roentgen rays. The greater evidence of the changes at the site of irradiation indicates, apparently, the greater significance of the direct influence of radiation on nucleic acids.

The Ministry of Public Health of the USSR

THE BIOSYNTHESIS OF PURINES AND THE METABOLISM OF THEIR PRECURSORS IN THE NORMAL STATE AND FOLLOWING ROENTGEN IRRADIATION

G. A. Kritsky

With the help of paper radiochromatography, products formed from the precursors of purines, glycine-1- C^{14} and $C^{14}O_2$, as well as formic acid- C^{14} , were detected in and separated from a homogenate of pigeon liver. Thus, in experiments with glycine-1- C^{14} twelve fractions were developed, the majority of which were identified: nucleotides (adenine and hypoxanthine), inosine, hypoxanthine, malic, succinic, fumaric, glycolic, and glutamic acids, serine, glutamine, alanine, methionine and others. Some of the properties of a few of the unidentified fractions were studied, among which were detected substances participating in the synthesis of purine fractions: fractions 2a, 2b and 9 from the experiments with glycine-1- C^{14} and fraction 5 from the experiments with formic acid- C^{14} . Among the indicated fractions C^{14} is included chiefly in the adenine group of adenylic acid and in the hypoxanthine group of inosinic acid, not in free hypoxanthine. Free hypoxanthine added to the liver homogenate is practically not included in the nucleotides. This indicates the necessity for a reaction of ribosidation of the purine precursor in the biosynthesis of purines.

A study was made of the effect of general roentgen irradiation of pigeons (with a dose of 2000 r) on the biosynthesis of hypoxanthine from glycine-1- C^{14} , using liver homogenates prepared at different periods after irradiation.

With the help of radioautography, as well as by measuring the activity of the preparations, it was shown that in the IL or homogenates of irradiated pigeons the synthesis of hypoxanthine, judging by the inclusion of glycine-1- C^{14} , had increased immediately after irradiation and had sharply decreased (by approximately 50%) during the following days.

Data on the effect of roentgen irradiation on the biosynthesis of hypoxanthine would be a matter of interest both in the study of the effect of radiation on the synthesis of purines, which are structural components of nucleic acids, and in the study of the effect of radiation on the biosynthesis of the end products of nitrogen metabolism, inasmuch as the principal portion of hypoxanthine in the organism is transformed into uric acid.

The A. N. Bakh Institute of Biochemistry of the
Academy of Sciences of the USSR

THE INTENSITY OF THE INCLUSION OF GLYCINE AND ACETIC ACID IN GLYCOGEN AND PROTEINS OF RATS' TISSUES AFTER EXPOSURE OF THE ORGANISM TO IONIZING RADIATION

S. F. Epshtein

The present work is devoted to a study of the influence of ionizing radiation on the intermediate metabolic processes in an organism, more precisely its influence on the intensity of utilization of carbon from the two-carbon compounds, glycine and acetic acid. The intensity of utilization of carbon from these compounds was judged by the radioactivity of proteins and glycogen isolated. Research was conducted on white rats. The irradiation dose was 650 to 800 r. After establishing the extent of utilization of labeled two-carbon compounds in the synthesis of proteins and glycogen in control animals, a study was made of the influence of irradiation on the indicated processes.

According to the data obtained, the radioactivity of the proteins of skeletal muscles decreased noticeably during the first 10 to 15 days after irradiation of the animals, while in cardiac muscle it increased during the same period. These data attest to a difference in the reactions of skeletal and cardiac muscle to the action of ionizing radiation. Irradiation did not exert a noticeable effect on the utilization of glycine in the synthesis of proteins by hepatic tissue, while the injection of labeled acetic acid increased their radioactivity. A different picture was observed in the kidneys. During the development of the symptoms of radiation sickness in the rats, the radioactivity of proteins, in the presence of injection of the animals with glycine and acetic acid, increased significantly.

It should be pointed out that the radioactivity of tissue proteins in the case of injection of acetic acid- C^{14} is 30 to 40% lower than in the case of injection of glycine- C^{14} . These observations are explained by the direct participation of glycine in protein synthesis, while the course of utilization of acetic acid in this process is more complex.

The utilization of acetic acid in glycogen synthesis in irradiated and control animals was also demonstrated.

The most glycogen radioactivity in the controls was found in the liver, then in cardiac muscle and, finally, in skeletal muscle.

In the irradiated animals the radioactivity of glycogen in the skeletal muscles fluctuated for 12 days after irradiation. After this time it doubled itself. A somewhat different picture was observed in cardiac muscle: for the first four hours after irradiation glycogen radioactivity increased significantly, within 24 hours had returned to its original level, and after 12 days experienced another increase.

The glycogen content of skeletal muscles and liver was substantially unchanged at different periods after irradiation of the animals; in cardiac muscle it decreased about the 12th day after irradiation. Facts established in the experiment indicate the intensive utilization of acetic acid in glycogen synthesis in the presence of a reduction in its content. The radioactivity of glycogen in the liver of irradiated animals did not change.

On the basis of the experimental work conducted it can be concluded that ionizing radiation influences the processes inducing utilization of acetic acid and glycine in the synthesis of proteins and glycogen.

The A. N. Bakh Institute of Biochemistry of the
Academy of Sciences of the USSR

CHANGE IN THE METABOLISM OF CONNECTIVE TISSUE PROTEIN STRUCTURES IN ACUTE RADIATION SICKNESS PRODUCED BY ROENTGEN RAYS.

L. T. Tutochkina, N. D. Petrova, V. V. Shikhodyrov and L. I. Polilarpova

In acute radiation sickness intensified disintegration of collagen structures occurs in the skin of rats and mice. The following changes attest to this fact: a) swelling, homogenization and augmentation of chromotropy of collagen fibers in histological preparations, b) retardation of inclusion of glycine- C^{14} in procollagen and insoluble collagen, c) a significant decrease in skin mass. While the relative total protein content of the skin did not change, the yield of the procollagen fraction changed negligibly.

The disturbances described in the metabolism of collagen proteins are not specific for radiation sickness. They are observed in the development of a negative nitrogen balance in an organism independently of the causes producing this condition; similar changes are observed in healthy animals particularly during strong hunger.

The factors producing the development of a negative nitrogen balance and the destruction of collagen proteins are not the same in different stages of radiation sickness.

Intravenous injection of mice with chondroitinsulfuric acid prior to irradiation prevents the metabolic changes of procollagen in the early stage of radiation sickness and increases the survival rate of the animals.

The disturbance of the metabolism of connective tissue protein structures in radiation sickness is one of the factors leading to the development of hemorrhagic diathesis.

The Ministry of Public Health of the USSR

THE EFFECT OF IONIZING RADIATION ON THE CHANGE IN THE COMPONENTS OF THE ENZYMIC REACTION OF LIPOID METABOLISM IN PLANTS

E. V. Budnitskaya and T. G. Borisova

The biochemical reactions occurring in plants under the influence of ionizing radiation, in particular the processes disturbing lipid metabolism as a result of irradiation, have been only slightly studied. In the present work a study was made of the effect of ionizing radiation on the substrates and enzymes of lipid metabolism in plants. The effect of roentgen rays was studied using lipoxidase from soy meal and from shoots of different plants.

It was shown that a preparation of lipoxidase extracted from the soya is inactivated by roentgenrays; the extent of inactivation depends on the intensity of the radiation and the state of the lipoxidase. It was established that the enzyme lipoxidase *in vitro* possesses sufficiently high resistance to the action of radiation; in connection with this fact, the mechanism of the inactivation of lipoxidase was studied, and through a new method of radiation inactivation the molecular weight of this enzyme was determined.

In experiments *in vivo* there was established a greater sensitivity of lipoxidase in the leaves of different plants to the action of ionizing radiation (approximately 30 to 50 times as great), a fact which can be explained by changes in cell permeability and the availability of the substrate to the action of the enzyme.

It was found that the substrates of lipoxidase, linoleic acid and carotene, which are provided by the lipoxidase system in the attendant reactions, are oxidized spontaneously *in vitro* more rapidly as a result of irradiation than without irradiation. In the case of irradiation of solutions of a mixture of linoleic acid and carotene, the oxidation of linoleic acid increases the attendant oxidation of carotene. But, as was shown by the determination of the oxidative destruction of carotene and linoleic acid in the presence of different doses of irradiation, the lipoxidase substrates possess considerable resistance to the effects of radiation, a fact which indicates the minor importance of their nonenzymatic oxidation in changes in lipid metabolism resulting from small doses of irradiation.

The greater sensitivity of the lipids to the effects of ionizing radiation was established directly in plant leaves, where it showed up as a significant increase in the quantity of oxidation products of unsaturated fatty acids peroxides, to which a considerable role is attributed in the intoxication of a living organism resulting from irradiation; this can be explained by changes in cell permeability resulting from radiation and apparently consequent disturbances in the metabolism and integrity of the plant organism.

The A. N. Bakh Institute of Biochemistry of the Academy of Sciences of the USSR

RADIOSTIMULATION OF PLANTS AND ITS POSSIBLE THEORETICAL INTERPRETATION

N. V. Timofeev-Resovsky and N. V. Luchnik

In experiments extending from 1949 on a dozen or so aspects of cultivated plants, it was established that small doses of roentgen, β - and γ -rays hasten growth and increase plant mass and harvest. A similar radio-stimulation was noted with different methods of irradiation both in laboratory and field experiments and in industrial sowings. In equal doses, sources of hard β -radiation produced greater stimulation than soft sources; α -particles under the same conditions did not produce stimulation, while radiation sickness increased rapidly with the dose. Irradiation with a dose of less strength promoted stimulation.

A cytological analysis showed that the suppression of growth observed as a result of large doses was correlated with the number of chromosomal disruptions in growing cells. Radiostimulation resulted in a slight decrease in cell size but a large increase in the number of dividing cells, this increase showing up particularly in prophase; there appeared simultaneously a significant number of symmetrically binuclear cells.

On the basis of analysis of the results of cytological experiments, the following conclusions were drawn. The basic reason for the suppression of growth resulting from the action of α -radiation and large doses of β -radiation is the death of cells in consequence of chromosomal ruptures and definite types of chromosomal aberrations. Stimulation of growth is linked with an increased tempo of cell division. In connection with speeding up of cell division, first of all nuclear division is hastened, and thus, to all appearances, the synthesis of deoxyribonucleic acid. Therefore, the hastening of the division of the plasmon and of protein synthesis is considered as a secondary phenomenon.

Biophysical analysis shows that the suppression of growth and its stimulation are in a certain measure independent processes, since they depend in a different manner on the linear density of ionization and on the time factor. The chromosomal disruptions leading to the death of the cells, the actual cause of suppression of growth, in order to be brought about require much energy concentrated in time and space. Mitotic stimulation requires a certain optimal energy diffusely distributed within the cell; there exists, moreover, a definite sensitive period occurring during interphase.

The hypothesis is formulated that the stimulation takes place as a result of the appearance in the cell, in very weak concentrations, of products of protein denaturation and "xenogenic" molecules as a result both of primary radiochemical effects and, possibly, of primarily induced chain reactions; under these conditions, as is well known, proteolytic and general enzymatic activity of a cell may be increased.

The Institute of Biology of the Ural Branch of the Academy of Sciences of the USSR

THE INFLUENCE OF IONIZING RADIATION ON BIOLOGICALLY ACTIVE SUBSTANCES IN CORN LEAVES

V. S. Fedorova and L. A. Sevastyanova

On the basis of data appearing in the literature on the stimulating effect of small doses of ionizing irradiation on seed sprouting, the growth of agricultural plants and increased yields, experiments were conducted to clarify the effects of small doses of ionizing radiation (irradiation of seeds with roentgen or γ -rays prior to

sowing) on the content of biologically active substances in corn leaves - ascorbic acid, chlorophyll, carotene and solid substances - and on several physiological processes.

The greatest ascorbic acid content in the plants, exceeding that of the controls by 30 to 50%, was observed in the reduced state during the early stages of development (sprouting and leaf formation).

During the latter stages of development the quantity of ascorbic acid decreased and in the cobs approached that of the controls.

Variations irradiated with 500 and 250 r showed the most energetic accumulation of ascorbic acid. Moreover, in these groups there was noted an earlier ripening in comparison with the controls.

A similar picture was observed with respect to the accumulation of carotene.

Under the influence of irradiation of seeds with γ -rays from Co^{60} , the largest amount of chlorophyll was detected in the variation irradiated with 500r, a somewhat smaller amount in the case of irradiation of seeds with 1000 r. A dose of 100 r did not produce an increase in chlorophyll in comparison with the control.

Analogous results were obtained with respect to the content of solid substances.

The data obtained make possible the assumption that irradiation of corn seeds prior to sowing with small doses increases the content of biologically active substances (ascorbic acid, carotene, chlorophyll and solid substances) in corn leaves and hastens the ripening process of the seeds.

The Botanical Garden of the Western Siberian Branch
of the Academy of Sciences of the USSR

SOME DISTURBANCES IN THE METABOLISM OF A SPROUTING CORN SEED UNDER THE INFLUENCE OF IRRADIATION

N. I. Berezina

In order to clarify the nature of the effect of ionizing radiation on dry corn seeds, histochemical studies were made of the separate tissues of irradiated seeds in the process of sprouting.

The material used was dry, half-ripened corn seeds, Voronezhsky type No. 76, irradiated with roentgen rays in doses of 40,000 and 16,000 r at a rate of 160 r per minute.

The histochemical studies were begun within 48 hours after soaking of the irradiated seeds. The starch granules in the endosperm of the nonirradiated plants about this time were stained blue-black with iodine in potassium iodide solution; the granules of the irradiated seeds were stained violet, and then a brown color typical of dextrans. The earlier conversion of starch into dextrin and of dextrin into sugar in the irradiated seeds can be regarded as the result of a strengthening of the hydrolytic activity of enzymes in the seeds under the influence of irradiation.

In the cells of the seed coat of the irradiated seeds, from 98 to 118 hours after soaking there was established a significantly greater quantity of lipoids than in the coats of the nonirradiated seeds.

During the conversion of the seedlings to autotrophic nutrition the cells of the seed leaves of the nonirradiated plants were filled with chloroplasts of a bright emerald-green color. In the seed leaves of the irradiated plants chlorophyll was not formed at all.

The absence of green coloration in the leaves of the irradiated seedlings (exposed to a dose of 40,000 r) indicates complete suppression of chlorophyll synthesis as a result of irradiation of dry corn seeds. In the case

of a smaller dose of irradiation of the dry seeds (16,000 r), chlorophyll was formed in the seedlings, but when planted in the field the irradiated plants lagged noticeably behind the controls in their growth, and in the 5 or 6 leaf stage they died.

When this same dose (16,000 r) was administered to green plants, no notable deviations in chloroplasts were observed.

Thus the effect of 16,000 r on the chloroplasts of a green plant did not produce any notable changes, whereas the exposure of dry seeds to this same dose caused a strong agglutination of chloroplasts and led to the death of irradiated plants.

The Institute of Biophysics of the Academy of
Sciences of the USSR

THE INFLUENCE OF γ -RADIATION FROM Co^{60} ON AGRICULTURAL PLANTS

O. K. Kedrov-Zikhman, A. F. Agafonova and A. N. Kozhevnikova

Radiation from the radioisotope Co^{60} can show both a positive and a negative influence on plants depending upon the type of plant and concomitant fertilizing. In this connection the positive effect of Co^{60} is manifested to a large extent in the reproductive organs and to a lesser extent in the vegetative organs.

Depending upon the content of Co^{60} in the organs located above ground, its influence on the crop is manifested differently. In the case of a negligible Co^{60} content in plants (grown on soils treated with lime, for example) a positive effect is most often observed on seed yield, while in the case of a higher content (on acid soils) the effect of Co^{60} on the yield may be weak; only plants characterized by a low content of Co^{60} (barley, flax), when cultivated in unlimed soil, react positively to its introduction into the soil.

Under the influence of radiation from Co^{60} on unlimed soil there was observed a decrease in the intensity of the consumption of carbon dioxide by beet leaves, while in the case of limed soil there was negligible increase, showing up only in determinations made during the morning.

The intensity of liberation of CO_2 by the leaves of the mangel-wurzel increased toward the end of the growing season on limed soil.

Under the influence of Co^{60} introduced into the soil, the rate of sucrose hydrolysis was increased, but the sugar content of beet leaves on limed soil as well as on acid soil became somewhat greater.

The All-Union Scientific Research Institute of
Fertilizers and Soil Science

THE INFLUENCE OF IONIZING RADIATION ON GROWTH AND INCREASED PRODUCTIVITY OF THE EUCOMMIA PLANT

A. Ya. Tolstopiat

β -radiation from radioactive isotopes shows a stimulating effect on the sprouting of eucommia seeds, the growth of the plant and the development of greater resistance to drought and low temperatures.

β -radiation from the radioactive isotopes P^{32} , Ca^{45} , S^{35} and C^{14} , administered to the plant through the roots and leaves, shows a varying degree of stimulation of gutta-percha formation in the leaves and a greater accumulation of gutta-percha (from 0.5 to 1% and higher).

The increased gutta-percha accumulation in eucommia leaves and the increased rate of plant growth are conditioned by the action of optimal doses of the sources of β -radiation and the duration of this action during plant growth.

The low frost resistance of eucommia plants is explained chiefly by the high degree of photosynthetic activity of the leaves and the intensity of plant growth lasting until midautumn, in consequence of which the wood is still immature and soft at the onset of winter.

In this connection further research using radioactive isotopes as sources of radiation may provide long-range perspectives for increasing the strength and frost resistance of this valuable crop.

The Ukrainian Scientific Research Institute of Forestry and Forest Amelioration

THE EFFECT OF γ -NEUTRON RADIATION ON MICROORGANISMS

T. S. Remezova

A study of the effect of high-speed neutrons on microorganisms was conducted with the aim of examining the possibility of utilizing neutron streams to regulate the vital activities of microbes under natural and artificial conditions. Only a small amount of work on this question is known.

Experimental work testing the effect of γ -neutron radiation on different types of sporogenous and non-sporogenous bacteria and yeast was done in the atomic reactor. Special experiments were conducted to study the effect of the radiation of the reactor on the microflora of soil.

The soil specimens studied, bacteria suspensions and compressed yeast were placed in sterile, hermetically sealed containers made of "organic glass", in which they were lowered into the zone of maximal neutron density, the functioning channel of the reactor.

The dose of radiation was changed by regulating the time the specimens remained in the reactor.

The results obtained in this manner showed that γ -neutron radiation of an atomic reactor possesses a powerful bactericidal effect. In the presence of a stream of high-speed neutrons with a density of 1.2×10^{11} neutrons/cm²/minute and γ -radiation of 2000 r/minute, a culture of *B. coli* containing 4.0 to 8.0×10^8 cells per ml became sterile after a two-minute irradiation in the reactor. After exposure under these same conditions for 5 to 10 minutes, 100% of the yeast organisms and sporogenous bacteria were inactivated. However, suspensions of bacteria and yeast—in which not a single cell was preserved after neutron irradiation that was capable of reproducing or forming colonies in a nutritive medium—respired energetically and fermented sugar.

These data indicate that different functions of the vital activity of microorganisms possess different degrees of resistance to the effects of γ -neutron radiation. A more abrupt disturbance is characteristic of doses of neutron radiation, which damage the reproductive function of the microorganisms and fundamental metabolic processes (respiration and fermentation), in comparison with the effect of roentgen rays on these systems. A morphological study of the structure of yeast cells also revealed characteristic morphological changes which appeared in the case of incubation in a nutritive medium of the cells irradiated with neutrons. Such organisms in attempting to grow formed gigantic degenerative cells with enlarged, swollen nuclei, altered karyosomes with odd bulges, and membrane disturbances. Further attempts to grow resulted in the bursting of the cells and immediate death. However, the most specific indicator of the effect of neutrons on microorganisms is induced radioactivity. After a two-minute irradiation of the cultures in an induction reactor, the radioactivity in one gram of dry cellular material amounted to hundreds of thousands of disintegrations per minute. However, as a result of the disintegration of the short-lived isotopes, the induced radioactivity of the cells decreased rapidly during the first hours and days after irradiation and then remained stable for several weeks. In this work the induced activity of the material irradiated with neutrons was used to estimate the reproducibility of the conditions of irradiation and the commensurability of the doses absorbed by the specimens with different intensities of irradiation and durations of exposure. From cultures of *Saccharomyces cerevisiae* irradiated with sublethal doses, mutants were segregated which were deficient in inositol and which could be used as indicator organisms in the quantitative determination of inositol.

The Institute of Microbiology of the Academy of Sciences of the USSR

A STUDY OF THE EFFECT OF NEUTRONS ON THE GROWTH AND DEVELOPMENT OF PLANTS

S. P. Tselishchev and V. B. Mogilevkin

The irradiation of seeds of experimental plants was conducted in a field of purely thermal neutrons and in a mixed field of high-speed, intermediate and thermal neutrons of a nuclear reactor. The calculation of the tissue dose was made on the basis of a known integral neutron stream, the energy spectrum of neutrons and the chemical composition of the seeds. The neutron stream was recorded by activation detectors. The accompanying dose of γ -radiation was determined by chemical dosimetric methods.

The sensitivity of different plants to neutron radiation is not the same. In order of increasing sensitivity, determined by seed yield, the plants studied assume the following sequence: mustard, radish, millet, soya, oats, wheat, kidney bean and pea. The differences in sensitivity to neutrons of different plants under equal conditions of irradiation depend on both the elemental chemical composition of the irradiated tissue and the biological properties of the different types of plants.

Neutron irradiation of the seeds leads, as a rule, to suppression of the growth of the plants. In experiments on the pea, in which the dried seeds were irradiated with thermal neutrons, the dose value was set at 50% survival. A definite regularity was discovered in the growth of the irradiated pea plants, which consisted in a progressive growth lag of the experimental plants, reaching a certain maximum lag on the 10th or 11th day of development. The total extent of the maximum suppression, and the rate and degree of the succeeding levelling off with the control are determined by the dose absorbed and the physiological state of the irradiated seeds (both dry and swollen). It was also shown that there are shifts toward retardation in the phase development.

It was established that soaking the seeds in a solution of H_2O_2 led to an increase in the radiobiological effects of thermal neutrons which was not proportional to the increased tissue dose. An attempt was made to evaluate the relative biological effectiveness of the different nuclear radiations generated in tissue by the neutrons.

Irradiation of seeds with predominantly thermal neutrons resulted in the activation of the majority of the atomic nuclei contained in the tissue. The accumulation of induced activity in the tissue dose of neutrons was negligible. Induced activity, however, can be used as an indicator in the study of the transfer of phosphorus and calcium from the irradiated seeds into the sprouts, and also for an approximate relative evaluation of the integral neutron stream under different conditions of irradiation.

In a study of the distribution of P^{32} produced by neutrons in plant tissue, it was established that the greatest specific activity of all the phosphorus-containing compounds is possessed by the nucleoprotein fraction; the phosphorus, being stably bound in the nucleoproteins, is not notably displaced in isotopic exchange reactions. The predominant localization of induced P^{32} in the nucleoproteins can be explained by the high degree of reactivity of protein molecules lightly binding the "hot atoms" of P^{32} driven out of other phosphorus compounds in neutron- and gamma-induced reactions.

The K. A. Timiryazev Moscow Agricultural Academy
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THE INFLUENCE OF IRRADIATION ON THE STRUCTURE AND CERTAIN PHYSIOLOGICAL PROPERTIES OF MICROORGANISMS

M. N. Shalnova

The practical use of radiation sterilization requires a detailed study of the effects of large doses of ionizing radiation both on microorganisms and on the substrate being sterilized.

The aim of the research was to shed light on the influence of sterilizing doses of ionizing radiation on morphological and certain physiological properties of microorganisms.

The object of both morphological and physiological studies was the yeast plant *Endomyces magnusii*. A portion of the experiments was conducted with spores of *Bac. megatherium*. The sources of irradiation were a BF roentgen tube with a dosage power of 15,000 r/min and a cobalt apparatus giving 4860 r/min. The irradiation dose was 1,000,000 r.

As a result of the research, it was established that under the influence of sterilizing doses of ionizing radiation, there occurs a substantial disturbance in the structural organization of the microbial cell.

In spite of the distinct structural disorganization of the protoplast of the microbial cell, the irradiated microbes preserved for a more or less protracted time certain physiological and biochemical functions. They manifested a clear tendency toward growth and preserved partial capacity for respiration, fermentation and fat and sterol formation. Following the sterilizing doses of irradiation, the spores displayed the initial signs of germination.

In the biological substrate, sterilized by irradiation, factors activating the respiration of indicator microorganisms were successfully detected.

It turned out, that combined radiation and thermal treatment made it possible to lower the irradiation dose necessary to inactivate the spores; in this connection, heating prior to irradiation was more effective than after irradiation.

The Institute of Microbiology of the Academy of Sciences
of the USSR.

THE CONDITIONS OF INCREASED BIOSYNTHESIS OF ERGOSTEROL BY YEAST PLANTS

R. D. Galtsova and I. P. Bakina

A study of the conditions of increased synthesis of ergosterol by yeast plants permits one to approach a deciphering of the mechanism of the biological synthesis of sterols and to mark the path by which are obtained the raw materials required for drug and vitamin production.

From material appearing in the literature as well as from data obtained by the authors, it is known that yeast of the genus *Saccharomyces* is richest in ergosterol content. A selection was made of productive (with respect to ergosterol) strains belonging to the species *Sacch. carlsbergensis*.

It was established that ionizing radiation produces a significant increase (a doubling) in ergosterol content in yeast plants.

The most favorable culture media for the biosynthesis of ergosterol are those containing a great abundance of carbon to the complete exclusion of nitrogenous nutriment. The best sources of carbon turned out to be glucose, sucrose and pyroracemic acid; these substances make it possible to increase the yield of ergosterol by twice and even more.

It was a matter of interest to shed light on the joint effect of roentgen irradiation and unilateral carbon alimentation on the accumulation of ergosterol by yeast plants.

As was shown by the results of the experiments, within a day the irradiated yeast kept on glucose yields an appreciable increment of ergosterol in comparison with the amount of the sterol formed in other culture media. After the first day the ergosterol increment in *Sacch. cerevisiae* (A) kept on glucose was 250%, after the second day 280%, and after the third day 303%.

The ergosterol yield was still more significant when yeast with a high capacity for the biosynthesis of ergosterol was used in the experiments. When such cultures were irradiated and subsequently kept on 2% glucose, the quantity of ergosterol by the 5th to the 6th day reached 12 to 14% of the dry weight of the yeast.

Consequently, with combined irradiation and unilateral carbon alimentation, productive strains of yeast can yield many times more ergosterol than that presently obtained in the industry.

The Institute of Microbiology of the Academy
of Sciences of the USSR

III. MEDICAL RADIOLOGY

THE EXPERIMENTAL USE OF RADIOACTIVE ISOTOPES IN THE DIAGNOSIS OF CARDIOVASCULAR DISORDERS

K. G. Nikulin

The paper sums up a three-year experiment of the Chair of Propaedeutics of Internal Diseases of the Gorky Medical Institute on the use of radioactive isotopes in the diagnosis of rheumatism, atherosclerosis and hypertensive vascular disease.

A comparison of the percentage of inclusion of iodine in the thyroid gland with the clinical picture in cases of rheumatism provides the basis for considering that increased thyroid function can serve as a supplementary test in diagnosing the activation of rheumatism.

A study of the dynamics of the inclusion of radiolodine in the thyroid gland in atherosclerosis showed that decreased inclusion of iodine is a test which supplements the data of electrocardiographic examination and cholesterol metabolism in atherosclerosis.

A change in the function of the thyroid gland in hypertensive disease, in conjunction with electrocardiographic data, basal and cholesterol metabolism, supplements the possibilities of diagnosing the sclerotic stage of hypertensive vascular disease.

The Gorky Medical Institute

A METHOD OF ANALYZING THE RESORPTION OF Na^{24} FROM THE INTRACUTANEOUS DEPOT AND ITS USE IN A CLINIC FOR INTERNAL DISEASES

A. L. Syrkin

An examination of the permeability of tissues and capillaries is of interest in a number of illnesses. The existing methods of examination, however, have a number of shortcomings. With the discovery of radioactive isotopes, the possibility arose of injecting tracer substances and following the rate of their entry into the general blood stream.

The method employed consists in the intracutaneous injection of $1 \mu\text{c}$ of Na^{24} in 0.2 ml of physiological salt solution and the construction of a graph of decreasing activity for the injected part during 15 to 20 minutes. As an indication of the rate of resorption, the resorption constant determined by Katy, was selected.

In the absence of disturbances in permeability, water metabolism or circulation, the resorption constant in adults is 0.072 to 0.116.

The experiments succeeded in demonstrating the influence on the rate of resorption of Na^{24} of a number of factors which play an important role in the pathogenesis of many illness (disturbance of water metabolism, retardation or hastening of blood flow). Among patients with thyrotoxicosis, the resorption of sodium is hastened. Examination of patients with erythremia revealed a retardation of resorption. A significant retardation of resorption was detected among patients with decompensated heart defects. It was less marked in the initial stages of decompensation.

In examinations of 100 patients with rheumatism, there was noted both a retardation and a hastening of resorption. Hastening of resorption was linked with increased permeability of the vessels and connective tissue,

while retardation was linked with inadequate blood circulation, which is usually observed in cases of repeated attacks of rheumatism.

The Sechenov First Moscow Order of Lenin
Medical Institute.

RADIOACTIVE ISOTOPES IN A STUDY OF HISTOHEMATIC BARRIERS IN A CLINIC FOR NERVOUS DISEASES

I. L. Vaisfeld, A. M. Vein, N. I. Grashchenkov,
M. B. Dunaevskaya, B. I. Kamenetskaya and G. N. Kassil

In certain disorders of the central and peripheral nervous systems a study was made of the permeability of: 1) capillaries of the skin in direction of tissue to blood; 2) the vessel wall in direction of blood to tissue; 3) the hematoencephalic barrier. Radioactive isotopes (P^{32} and Na^{24}) served as indicators of permeability.

Under observation were: 1) patients with damage to the diencephalic, chiefly the hypothalamic region (with autonomic and vascular disorders, neuroendocrine disturbances, various neurodystrophic syndromes, etc.); 2) patients with different pathological processes, the fundamental manifestation of which was a marked painful syndrome; 3) patients with cranioencephalic traumata; 4) patients with brain tumors.

Characteristic changes in permeability of skin capillaries and vessel walls were determined.

Definite regularities were shown to characterize the state of the hematoencephalic barrier in cases of cranioencephalic traumata and brain tumors. A study was made of the distribution of P^{32} in the tissues of different sections of the brain and in brain tumors. It was established that the increase in permeability of the hematoencephalic barrier is accompanied by an accumulation of acetylcholine and an increase in the activity of hyaluronidase in the cerebrospinal fluid.

Methods of acting on the hematoencephalic barrier were worked out which make it possible to raise and lower its permeability in clinical practice.

The Central Institute for the Perfection of Physicians

THE USE OF SODIUM 24 IN A STUDY OF BLOOD CIRCULATION IN A STUMP WHEN AMPUTEE STANDS AND WALKS WITH PROSTHESIS

V. S. Gurfinkel, T. S. Vinogradova,
Ya. L. Slavutsky and I. B. Sklyar

Utilization of radioactive indicators made possible a study of blood circulation in a stump when a prosthesis is used.

In the first part of the work, a study was made (on 9 examinees) of blood flow of tissues in the skin and muscles of the stump of a thigh with Katy's technique. The control group was made up of 15 practically healthy examinees. Subsequently, a three-stage form of examination was employed, which made it possible to compare the intensity of absorption of Na^{24} under different conditions (lying, standing and walking) in a single experiment.

The examinations established the fact that blood flow in the tissues of a stump practically does not differ from normal circulation. Disturbances existed only near where the bone had been sawed.

When the patient stood with uniform weight on the sound leg and the prosthesis, the constant of absorption—the percentage absorption of the indicator per minute—was significantly lowered, while the time of absorption of 50% of the indicator was increased. When the amputee leaned only on the prosthesis, tissue circulation ceased altogether.

The examinations showed that walking results in an increase in tissue blood flow in the stump, compared with that at rest. The fundamental factors promoting this condition are active hyperemia and muscular action.

Thus, the use of a prosthesis is accompanied by characteristic changes in the blood supply, as a result of which the required blood supply level is maintained.

The Central Scientific Research Institute of
Prosthetics and Prosthetic Manufacture

THE USE OF RADIOACTIVE IODINE TO STUDY THE FUNCTIONS OF THE THYROID GLAND IN DISORDERS OF THE INTERNAL ORGANS

L. N. Kazakova

An examination of the functional state of the thyroid gland is quite important not only in the diagnosis of endocrine disorders, but also in a clinic for internal diseases.

A study was made of the function of the thyroid gland in 126 patients with different disorders of the internal organs: 36 had kidney disorders, 60—rheumatic heart disease, 30—liver disorders.

Among the patients with kidney disorders, in 19 cases the diagnosis was chronic nephritis of the nephrotic type, in 5 cases—amyloidosis of the kidneys, in 12 cases—chronic nephritis of the hypertonic type. It was shown that the period of exacerbation of the kidney inflammatory process was accompanied by increased absorption of radioactive iodine by the thyroid gland. Improvement in the patient's condition resulted in a decrease in the absorption of radioactive iodine. It was also observed that in chronic nephritis, improvement may occur after treatment for concomitant hyperthyroidism.

The results of clinical examinations support the experimental data of Sheigerts (1946), which showed experimentally a pathomorphological link between inflammatory kidney disorders and the functional state of the thyroid gland. In this connection, it was shown that the period of exacerbation in chronic nephritis is accompanied by increased thyroid function, while the hyperthyroidism attendant upon nephritis may aggravate the course of the latter. Treatment of the kidney condition in the case of accompanying hyperfunction of the thyroid gland reduces the latter, and, conversely, treatment of existing hyperthyroidism in a patient with nephritis has an ameliorating effect on the kidney disorder. Among 13 patients with marked nephrotic syndrome, hypofunction of the thyroid gland was detected in seven and hyperfunction in six. The method employed can aid clinicians to establish indications for the use of thyroid in the case of a significant nephrotic syndrome.

The second group of patients was made up of 60 persons with rheumatism. In nine of them, there were clinically evident signs of hyperthyroidism. Among 48 patients in the active stage of rheumatism, increased thyroid function was shown in 40. Of 12 patients in the latent stage of rheumatism, normal thyroid function was observed in almost all.

In cases of heart disease, with inadequate blood circulation of the first and second degree, increased absorption of radioactive iodine by the thyroid gland was observed in 28 out of 40 patients; in three patients with inadequate blood circulation of the third degree, decreased absorption was observed.

On the basis of observations conducted, it was noted that in the active stage of rheumatism, there occurs a significant increase in the function of the thyroid gland, while in the latent period, the normal function prevails. In cases of heart disease with inadequate blood circulation of the first and second degree, both normal and increased function are found; in third degree cases, a lowered function results.

The third group was comprised of 30 patients with liver ailments. In this group, nine patients were observed in the acute stage of Botkin's disease. In eight of them there was observed an increase of 33 to 50% in the accumulation of I^{131} in the thyroid gland. These observations indicate that in cases of disturbed liver function the thyroid function is also disturbed, and increased thyroid activity results.

Thus, the method of examining the function of the thyroid gland by means of radioactive iodine makes it possible to establish its functional state and the presence of links between the activity of the thyroid gland and the state of internal organs.

The Sechenov First Moscow Order of Lenin
Medical Institute

* Epidemic hepatitis.

DETERMINATION OF THE FUNCTIONAL STATE OF THE
THYROID GLAND IN PATIENTS WITH CERTAIN DERMATOSES
USING RADIOACTIVE IODINE

F. I. Sukhovy

1. The leading role of nervous factors in the pathogenesis of skin ailments is beyond doubt. However, an analysis of the data appearing in the literature and of our own observations convinces us that in the development of certain dermatoses, along with nervous disturbances, the glands of internal secretion have considerable importance, especially the thyroid gland.
2. A study of the role of the thyroid gland in the development of pathological processes in the skin was conducted by the method of radioactive indicators.
3. The study was made on 35 patients with eczema of different form and duration and 31 patients with various itching dermatoses. Twenty patients with urethritis of varying etiology and eight practically healthy subjects served as controls.
4. Our observations showed that the percentage of accumulation of I^{131} in the thyroid gland fluctuates within wide limits among healthy persons.
5. In order to study the function of the thyroid gland in patients with eczema and other dermatoses, we determined both its concentration capacity and its hormonal activity. Analysis of our data revealed a lowered I^{131} content in the gland in comparison with the normal state, as well as a relative inadequacy of the thyroid hormone.
6. The checking of hormonal secretion from the thyroid gland among patients with skin diseases attests to the lowering of the thyrotropic function of the pituitary gland; consequently, the thyroid gland possesses two-fold regulation: neuroconductive and humoral.

The Kharkov Scientific Research Institute of
Dermatology and Venereology

A STUDY OF THE ACTIVATION OF HEMATOPOIESIS
IN ANEMIC DOGS WITH THE USE OF RADIOACTIVE IRON

F. N. Babadzhanyan

The task has been proposed of explaining the variations in accumulation of iron (Fe^{59}) among the organs of dogs with posthemorrhagic and phenylhydrazine anemia and also of specifying the influence on hematopoiesis of the radiation emitted by the indicator doses of Fe^{59} .

The data obtained showed that after the injection of radioactive iron into anemic dogs there was a sharp rise in its deposition in the liver, spleen and bone marrow. This phenomenon is the result of compensating processes which guarantee the replenishment of lost iron reserves.

Previous research has shown that indicator doses of radioactive iron do not influence hematopoiesis in healthy dogs and stimulate the regeneration of erythropoiesis in cases of posthemorrhagic and phenylhydrazine anemia.

The paper was richly illustrated with experimental records.

The Uzbekistan Scientific Research Institute
of Blood Transfusion

THE USE OF RADIOACTIVE ISOTOPES IN SURGERY
AND TRAUMATOLOGY

N. N. Priorov and V. A. Polyakov

For several years, V. A. Polyakov, making use of radioactive isotopes, has been conducting a study of the consolidation process following simple and compound fractures, both under ordinary conditions and under particularly unfavorable conditions, as, for example, in the case of the action of ionizing radiation.

A study is being made by A. S. Martens, of local impairment of blood flow in patients suffering from electric shock. Na^{24} is being used as an indicator. Work is also being conducted on a study of those changes in tissue circulation which are observed in cases of internal damage to the knee among athletes.

Interesting research has been done with Na^{24} in a study of local blood circulation in tissues of the thigh stumps of invalids using prostheses with vacuum-braced cases (by V. P. Boyanskaya).

A study is being conducted of blood circulation in Filatov's stalk during different stages of its formation and maturation and also of blood flow in newly created digits of the hand (fingers created by V. N. Blokhin's method).

But the field of application of radioisotopes to surgery, traumatology and orthopedics is far from exhausted by the work mentioned.

If a radioactive indicator is introduced into narcotic substances, then the problem of the distribution and action of narcotic substances may be resolved.

With the use of labeled penicillin, the path of the antibiotic may be examined, as well as its "fate" in the organism, and the mechanism of its action may be specified to a greater extent.

It would be necessary to combine this research with a study of the development of microorganisms in different wounds. The possibility of using labeled microbes which exists at the present time, should be employed in order to solve one of the fundamental problems of military surgery — the question of the infection of wounds, of the ways in which bacteria are spread in cases of damage to soft tissues, bones, vessels, nerves and brain. Labeled microbes and antibiotics afford the possibility of shedding light on the periods of development of infection, the interrelationships between tissues and bacteria, bacteria and antibiotics, the nature of delayed treatment of wounds, and the effectiveness of this or that antibiotic and their combinations, doses and methods of utilization.

The question of blood transfusion entails many problems, the solution of which is greatly facilitated by the use of radioisotopes.

There is reason for assuming that radioactive indicators will serve to illumine the obscure aspects of the etiology and treatment of ulcerative diseases, cholecystitis and intestinal obstruction. Radioactive calcium and phosphorus should be used to study the formation of stones in the urinary and bile ducts.

The state of the peripheral vessels, the presence of spasms and thromboses and their obliteration may also be scrutinized with the use of Na^{24} .

New perspectives will be provided by the use of radioactive indicators in the study of the physiology and pathology of bone tissue.

It is imperative to underline the urgent need for the working out of more perfect methods of treating bone tumors with radioactive isotopes concentrated in bone tissue.

Finally, radioactive isotopes possessing sufficiently strong γ -radiation can be utilized for radiography of bones in cases calling for treatment of remote sites.

There exists the prospect of employing ionizing radiation for the sterilization of surgical instruments and dressings. This method of sterilization is particularly convenient in surgery.

The Central Institute of Traumatology
and Orthopedics

THE ONE- AND TWO-CHANNEL SYSTEM FOR DETECTING BRAIN TUMORS WITH THE USE OF RADIOACTIVE IODINE

K. N. Badmaev

1. The use of radioactive iodine in the diagnosis of brain tumors increases the accuracy of topical diagnosis, a fact which is corroborated by the records of over 160 patients of the Oncological Division of The Professor A. L. Polenov Leningrad Institute of Neurosurgery.

Selectively concentrating in the zone of tumor growth, radioactive iodine creates a seat of γ -radiation, according to the maximum amount of which it is possible to judge the extent and location of the pathological center within the cranial cavity.

2. The method of examining the patient is as follows. After the thyroid gland is blocked with Lugol's solution, the patient takes internally 200 to 300 mc of I^{131} . The distribution of the latter in the brain tissues is studied with the use of a scintillation γ -encephalometer recording automatically in the form of scintigrams on the tape of a self-recording potentiometer.

3. The γ -encephalometer represents a variegated electronic apparatus, made up of radioprobe, a computer, recording potentiometer, roller-track, and supply and regulation units.

4. Recently, the γ -encephalometer has been technically perfected by replacing the single-channel system of detecting the center of activity with a two-channel system (which does not exist abroad). A method of bilateral encephalometry has been created which makes it possible to examine a patient's cranium on the right and left sides at the same time.

The paper reviews the advantages and disadvantages of the one- and two-channel methods of diagnosis of brain tumors on the basis of corresponding clinical records. Some consideration is given to the means of further perfection of the indicator method diagnosis.

The Professor A. L. Polenov Leningrad Scientific
Research Institute of Neurosurgery

THE ACCUMULATION OF RADIOACTIVE PHOSPHORUS IN TUMORS AND ITS SIGNIFICANCE IN THE DIAGNOSIS OF SUPERFICIAL TUMORS, METASTASIS AND CANCER OF THE CERVIX OF THE UTERUS

Z. E. Akimochkina and S. S. Shiffin

The successful fight against malignant neoplasms depends upon their early diagnosis. The development of new methods of diagnosis is, therefore, an urgent task. Several authors in this country and abroad, have attempted to employ radioactive isotopes for this purpose. We decided to study the accumulation of P^{32} in the tissues of malignant tumors of humans by examining postoperative preparations and by employing radioactive phosphorus in diagnosing superficial tumors, metastasis and cancer of the uterine cervix. Examination of the postoperative preparations of internal organs was conducted with the aim of studying the possibility of the future use of radioactive phosphorus in the diagnosis of patients with cancer of the internal organs.

In conducting these examinations, we employed the standard method, viz., an aqueous solution of disodium phosphate (Na_2HPO_4) was given to the patient per os in indicator doses in a 5% glucose solution on an empty stomach. The tabulation of impulses was accomplished by means of a dial meter in a special probe using a B-2 apparatus.

An examination was conducted of 100 patients in which there was histological occlusion. Malignant formations were present in 44 of the patients, and benign tumors in 56. A discrepancy between our conclusions and the actual histological occlusions was observed in 9% of the cases.

The study of the accumulation of P^{32} in tumors of the internal organs was conducted on postoperative preparations of the stomach, intestines and female reproductive organs, taken immediately after operation. A histological examination was made of the tissues of the organs under study. In all, 66 postoperative preparations of the stomach and intestines were examined and 163 postoperative preparations of female reproductive structures. Of this number, 87 preparations included malignant tumors. The study of the accumulation of P^{32} in the pathologically altered tissues was carried out by comparison with its accumulation in similar, but unaltered, tissues, the value of which was taken as 100%.

It was noted that the accumulation of P^{32} in malignant tumors amounts to 130 to 600%, while in the case of other pathological processes it amounts to 70 to 200%. The accumulation of radioactive phosphorus is dependent upon the histological structure of the tumor.

The increased accumulation of P^{32} in cancer enables us, in spite of a number of difficulties of a technical nature, to make use of the method of tracer atoms for the early diagnosis of cancer.

New prospects are afforded by the use of radioactive phosphorus in the diagnosis of tumorous growths; they are closely linked with the further perfection of measuring apparatuses.

The Sechenov First Moscow Order of Lenin Medical
Institute

THE DATA OF RADIOGRAPHY IN THE STUDY OF THE DISTRIBUTION OF RADIOACTIVE ISOTOPES IN ANIMAL ORGANISMS

V. A. Gremilov, L. E. Pakulina
and A. A. Stankevich

The purpose of the present work was a study of the distribution of the radioactive isotopes C^{14} (in tyrosine and glycine), P^{32} (in sodium and calcium phosphate), S^{35} (in methionine, sulfapyridine and barium sulfate), Sr^{90} (in strontium carbonate) and Au^{198} in animal organisms. Experiments were conducted on 64 rats and 16 rabbits.

The radioactive substances were injected into different tissues of the animals in the amount of 2.5 to 10 curies * per g of body weight. The animals were taken for examination over a period of from one to nine days.

The tissues to be examined were taken from the site of injection of the isotope, regional lymph nodes, liver, spleen, kidneys, lungs and heart. From these tissues histological sections were prepared for autoradiographs.

The autoradiographs were studied by means of a densitometer. The data obtained permits one to draw the following conclusions:

1. The radioactive isotopes of all the compounds tested by us enter the vital organs of an animal from the site of injection, but the rate of absorption of the isotopes and their concentrations in these organs are different.
2. The radioactive isotopes injected into tissues as aqueous solutions of their different compounds (glycine labeled with C^{14} , sodium phosphate labeled with P^{32} , and methionine labeled with S^{35}), are absorbed most rapidly and attain the highest concentrations in parenchymatous organs.
3. Those radioactive isotopes which were injected as water suspensions—barium sulfate (labeled with S^{35}) and colloidal Au^{198} —enter the parenchymatous organs more slowly and in lesser quantities; the latter has the advantage in injection into internal tissues because of its short half-life.
4. The experiments, conducted with slowly absorbed radioactive compounds, still do not enable us to determine the so-called coefficient of differential absorption, i. e., the ratio of the concentration of an isotope in a given organ to the amount of the isotope injected per g of body weight, nor do they permit us to form an opinion relative to the harmlessness of the radioactive compounds which we tested in the case of their injection into an organism in the quantities required for local treatment of tumors.

The Institute of Oncology of the Academy of
Medical Sciences of the USSR

*As in original. May be mc or μ c.

THE HISTORADIOGRAPHIC DISTRIBUTION OF RADIOACTIVE IODINE (I^{131}) AND METHIONINE- S^{35} IN THE THYROID GLAND

M. F. Merkulov

With the use of autoradiography in the work, a determination was made of the localization of two component parts of iodothyroglobulin, iodine and the sulfur of methionine, in the microstructures of a normal thyroid gland at different periods after the injection of labeled substances.

Experiments were conducted on male white mice weighing 100 to 150 g. The animals were decapitated after 5 and 20 minutes and 1, 4, 12, 24 and 48 hours following injection of radioactive compounds. The thyroid gland along with the trachea and esophagus were fixed in absolute alcohol, treated with xylene and sealed with paraffin. Serial sections of a thickness of 5μ were prepared from the tissues.

A comparison of three variations of the microautoradiographic method showed that the greatest resolving capacity can be obtained with use of a photographic plate. The histological treatment of the tissues which was employed, results in a washing out of substances acting chemically on the emulsion, a fact which, along with direct contact of the sections with the photosensitive layer, permits the elimination of protective packing.

On the basis of an analysis of autoradiographs of the serial sections of the thyroid gland, it can be concluded that the iodination of thyroglobulin is accomplished in the colloid or in any case at the boundary of the colloid, and the apical portions of the follicle cells. The iodine compounds of high molecular weight detected in the cells of the thyroid gland, in all probability, get there by way of the colloid. The possibility is not excluded, however, that in the histological fixing process cell proteins may unite even with iodine compounds of low molecular weight which are subject to secretion into the blood stream.

The localization of radioactive sulfur in the tissues of the thyroid gland at different periods after injection of methionine- S^{35} reflects the process of the secretion of protein into the follicle cavity and the process of its resorption.

The I. V. Stalin Second Moscow State
Medical Institute

THE THERAPEUTIC USE OF RADIOACTIVE IODINE IN THYROTOXICOSIS

V. K. Modestov and V. R. Klyachko

Treatment with radioactive iodine was carried out on 153 patients with thyrotoxicosis. In 105 cases the disorder was of moderate gravity, and in 48 cases thyrotoxicosis was of a grave form. 133 of the patients had diffuse goiter, and in 20 cases nodes were present in the stroma. The patients in the latter group refused surgical treatment.

The method of fractional injection of radioactive iodine was employed, a method which allows one to take into account the individual reactions of the organism. The moderate dose of radioactive iodine for the patients with diffuse goiter amounted to 8 mc and for the patients with nodes present in the stroma, 22 mc.

As a result of the treatment the symptoms of thyrotoxicosis were eliminated among 90% of the patients with diffuse goiter and among 50% of the patients with nodes present in the stroma. Of the group of patients

with diffuse goiter, the thyroid gland assumed its normal size in 73%; the normal size of the thyroid was regained in only 20% of the group with nodes in the stroma.

With use of the method of fractional injection of radioactive iodine, hypothyroidism requiring treatment showed up in 0.6% of our patients; according to the data in the literature, hypothyroidism shows up in 8 to 9% of the patients when the single injection method is used.

The duration of observation of the patients extended up to three years. The symptoms of radiation sickness were not observed. In the course of the observation of patients with continued euthyroidism for over six months after completion of treatment, relapses occurred in three patients; in those cases in which euthyroidism lasted more than a year, there were no relapses. The treatment of patients with thyrotoxicosis in the form of diffuse goiter proved to be a simple and highly effective method of therapy.

The Central Institute for the Perfection of
Physicians

THE EXPERIMENTAL USE OF P^{32} IN THE TREATMENT OF PATIENTS WITH ERYTHREMIA AND CHRONIC LEUKEMIAS

V. A. Beier

1. Twenty-five patients with erythremia and chronic leukemias were subjected to treatment with radioactive phosphorus. Apart from clinical examination, the bone marrow and peripheral blood were examined, the functional state of the liver and kidneys was determined, as well as the quantity of phosphorus eliminated from the body in the course of 10 to 20 days.

2. A determination of the amount of radioactive phosphorus in the blood showed that its principal mass is found in the erythrocytes; the amount of it in the plasma is significantly less.

After a dose of 6 mc of P^{32} (administered in three parts of 2 mc each), traces of it can be detected in the blood for an entire month.

3. A morphological study of bone marrow showed that after a dose of radioactive phosphorus both the absolute and the percentage content of erythroblastic elements is reduced, and a delay occurs simultaneously in the maturation of erythroblasts; this leads to a decrease in the number of erythrocytes and a reduction of hemoglobin in the peripheral blood. Along with the decrease in erythrocytes, a simultaneous reduction occurs in the number of leukocytes and blood platelets, but to a significantly lesser extent; There were no particular changes observed among the myeloid elements of the bone marrow. A dose of 6 mc in no case resulted in functional disturbances of the internal organs, the liver and kidneys in particular.

4. Radioactive phosphorus proved to be an effective means of treating patients with erythremia. It possesses a number of advantages over other methods of treatment — the absence of side effects, simplicity of dosage and fairly prolonged remissions.

Less effective were the result of treatment with P^{32} (in the same doses) of patients with chronic leukemias — granulocytic and lymphocytic; among these patients radiophosphorus was not more advantageous than other treatments (urethan, roentgentherapy).

5. The use of P^{32} is contraindicated in cases of anemia and thrombopenia in which there are manifestations of hemorrhagic diathesis.

6. The maximum elimination of radioactive phosphorus, both among patients with erythremia and those with chronic leukemias, occurs on the first day, more rarely on the second. The greatest quantity of radiophosphorus taken per os is eliminated in the urine, less in the feces.

The appropriation of phosphorus occurs more readily in acid medium, and more of it is eliminated in the urine.

Glucose increases the absorbability of P^{32} , while iron lowers it. A calculation of phosphorus and calcium content in the diet is necessary for improving the absorption of injected radioactive phosphorus, and in the case of lowered acidity of the gastric juice prescription of hydrochloric acid is indicated.

The S. M. Kirov Order of Lenin Military Medical
Academy

THE SIGNIFICANCE OF RADIOACTIVE PHOSPHORUS (P^{32}) IN THE TREATMENT OF POLYCYTHEMIA

S. A. Raevskaya

1. An analysis of data pertaining to 70 patients with polycythemia, who were subject to observation for as long as seven years, explains the results of treatment as dependent upon the special features of the course of the illness and the method of therapy.

2. The prolonged observation of patients makes it possible to draw conclusions about the significance of repeated use of radioactive phosphorus and to evaluate the complications observed.

3. The combined use of radioactive phosphorus and irradiation on the diencephalon is outlined.

4. An estimation of the rate of elimination of radioactive phosphorus from the organism furthers an understanding of the effectiveness of treatment of different patients.

The Sechenov First Moscow Order of Lenin Medical
Institute

THE USE OF RADIOACTIVE ISOTOPES IN THE TREATMENT OF CANCER OF THE ESOPHAGUS

Z. F. Lopatnikova

Among the malignant tumors, cancer of the esophagus is one of the most rapidly developing diseases, and one which presents an extremely grave clinical picture.

The duration of life of those afflicted who do not receive treatment (according to V. I. Kazansky) amounts on the average, to five months.

In the treatment of cancer of the esophagus at the present time, two methods are employed — surgery and radiation.

The value of the surgical method of treatment is reduced as a result of the small number of patients available for surgery and the high mortality rate after the surgical operation.

With the aim of expanding the indications for radiation therapy of patients with cancer of the esophagus and improving the results of the treatment, in the radiology department of the Institute treatment was conducted of 80 patients chiefly in the third stage of the disease: 25 of the patients were treated with a combined method (both external and internal irradiation with the GUT Co-400 apparatus).

The results obtained fully justify an insistence of wide use of radiation therapy in cancer of the esophagus, not only in its early stages but also in so-called "neglected" cases.

The V. M. Molotov State Scientific Research Institute
of Roentgenology and Radiology

THE USE OF RADIOACTIVE COBALT AND GOLD IN CANCER OF THE FEMALE REPRODUCTIVE ORGANS

E. P. Ivanitskaya

For the objective evaluation of the significance of radioactive cobalt as a substitute for radium mesothorium, we compared the reactions and complications observed in the treatment of 205 women suffering with cancer of the cervix of the uterus. Of this number, 103 received internal treatment with RaMs in combination with roentgentherapy and 102 were treated with radioactive cobalt in combination with roentgentherapy or teleroentgentherapy. The method of treatment of both groups of patients was approximately the same.

Our observations did not reveal any particular difference in the time of appearance and development of epithelization of the cancerous ulcer resulting from treatment with RaMs or Co⁶⁰. Neither did we observe necrosis of the vaginal wall.

Complications in the rectum appeared in approximately the same percentage of cases in both groups of patients. Complications in the urinary bladder and the general radiation reaction were more marked in the group of patients receiving RaMs.

Our experiment showed the effectiveness of the use of Co⁶⁰ and makes possible extensive introduction of this isotope into wide practice in the treatment of cancer of the cervix of the uterus.

Widening the possibilities of radiation treatment of malignant tumors, we worked out a method, together with A. V. Kozlovaya, of using colloidal radioactive gold on 31 patients with cancer of the female reproductive organs. In spite of the small number of observations, we were left with the definite impression that new prospects are afforded by the use of Au¹⁹⁸ in treating cancer of the external sexual organs and the vagina, in cases of metastasis in the vagina, and in cases of certain parametrial relapses following operation in connection with cancer of the uterus or ovaries. In cases of vascularization of the tumor, and in particular with exophytic forms, the injection of insoluble radioactive isotopes into the tumor serves no purpose.

We consider that the use of radioactive isotopes in medical practice will significantly widen therapeutic possibilities, especially in the case of radiation treatment of neglected forms of cancer of the female sexual organs.

The V. M. Molotov State Scientific Research Institute
of Roentgenology and Radiology

THE EXPERIMENTAL USE OF COLLOIDAL RADIOACTIVE GOLD IN MALIGNANT TUMORS OF THE FEMALE GENITAL TRACT

L. A. Novikova, M. A. Volkova, K. A. Agamova
and V. N. Kiseleva

1. The incurability of patients with cancer of the cervix of the uterus after radiation treatment is explained chiefly by the incurability of metastases in the regional lymph nodes. Cancer metastases in the regional pelvic lymph nodes, according to the data of the P. A. Gertsen State Oncological Institute, were detected among 10 to 11% of first stage cases and among 24 to 20% of second and third stage cases during surgery after previous radiation treatment.

2. The incurability of regional lymphatic metastases after combined radiation treatment for cancer of the cervix of the uterus is caused by their low radiosensitivity and the limited possibility of supplying the high nidal doses necessary in light of this fact, because of the deep parietal location on the one hand and, on the other hand, the ready susceptibility to damage of the organs adjoining the uterus (urinary bladder and rectum). For this reason, the dose for regional metastases is $2\frac{1}{2}$ to 3 times less than for the primary nidus.

3. Surgical removal of regional metastases in the majority of cases is not accomplished because of intimate coalescence with the large vessels and nerves.

4. For the purpose of increasing the nidal dose in metastatic regions with minimal damage to the surrounding tissues, the use of colloidal radioactive gold (Au¹⁹⁸) has proved expedient. Radioactive gold has a short half-life (2.7 days), because of which up to 70% of the radiation is used up within the first five days; it also emits predominantly β -radiation, a fact which should guarantee strongly limited biological effect. For the direct action of the radioisotope on the affected area, the method selected was that of direct injection into the pelvic metastases, through a transperitoneal section and through the vagina. The dose was 50 to 70 mc.

5. Aside from the treatment of pelvic metastases in cases of cancer of the cervix of the uterus, colloidal radioactive gold has been used in cases of inoperable tumors of the appendages, implantation of the abdominal cavity and ascites.

6. During treatment with radioactive gold, observations were made of the general and local reactions of the organism and the distribution of the isotope.

7. Careful and repeated study of the peripheral blood showed that one-and-two-stage injection of radioactive gold in doses of 25 to 100 mc into metastatic pelvic nodes and the abdominal cavity was not reflected in the erythrocyte count. With respect to the white blood cells, among the majority of the patients persistent leukopenia, lymphopenia and a decreased quantity of thrombocytes were observed.

8. Systematic examination of blood, urine and feces for radioactivity showed that there was none among the majority of patients. Only in separate cases the urine was radioactive from the second through the fifth day after injection of the isotope.

9. Treatment with radioactive colloidal gold (in a dose of 50 to 150 mc) is at times accompanied by more or less marked symptoms of radiation sickness.

*As in original.

10. The reduction, and at times the complete cessation, of pain and the improvement in the general condition must be attributed to the positive, although comparatively short-term, results obtained with injection of radioactive gold in regional metastases; injection of the isotope in the abdominal cavity in the case of malignant tumors of the ovaries may result in cessation of accumulation of ascitic fluid, improvement of the general condition and prolongation of the patient's life.

11. Previous observations of the use of radioactive gold permit us to consider that this method of treatment warrants attention, further study and perfection.

The Gertsen State Oncological Institute

THE TREATMENT OF CERTAIN FORMS OF PITUITARY DISORDERS WITH RADIOACTIVE COBALT

E. N. Mozharova

The leading method of treating acromegaly and adiposogenital dystrophy is radiation treatment. Roentgen-therapy applied in cases of these disorders does not exhaust all the possibilities of the radiation method, inasmuch as irradiation only from an external source is insufficient in severe cases (particularly in the case of affection of vision).

The supplementary use of the hard radiation of radium in filters is available in only a few institutions. The possibility of using Co^{60} both from an external source and in the filter method, as well as the homogeneous hard γ -radiation of Co^{60} , are valuable properties necessary for effective therapeutic action in cases of pituitary disorders.

The treatment of patients with acromegaly and adiposogenital dystrophy should, as a rule, begin with a conservative radiation method, and only in the event of a worsening of the disorder (particularly progressive loss of sight should the patient be referred to surgery.

Directing a patient to surgery prior to radiation treatment cannot be justified, since surgical operation for acromegaly and adiposogenital dystrophy even by the best surgeons results in 2 to 4% fatality; even should the patient live, the operation may prove to be without positive results or, in a number of cases, may result in grave complications.

Treatment with penetrating radiation is not connected with any risk and is borne easily by the patient, almost without reaction.

Treatment was carried out on 60 patients all told (49 with acromegaly, 11 with adiposogenital dystrophy).

The hypophyseal-hypothalamic region was subjected to irradiation from an external source with a radiographic apparatus using four fields; the superior cervical sympathetic ganglia were irradiated with one field from each side of the neck. Irradiation was conducted fractionally in doses of 150 to 250 r with an interval of one to three days. The total irradiation dose to the head was 2500 to 3000 r and to the cervical ganglia, 450 to 600 r. The field of irradiation was 7×7 cm; the distance was 7.5 cm.

Intracavity introduction of Co^{60} in filters was accomplished through the nasal passages under the sphenoid bone for 10 to 15 hours with a dose of 500 to 900 r; this increased the depth dose to 1500 to 2000 r.

One combination or another of the methods described above was used, depending upon the clinical symptomatology and the gravity of the disorder as judged from the individual symptoms.

Of the 60 patients, 32 were subjected to combined irradiation of the head and cervical sympathetic ganglia. Irradiation of the head in combination with the introduction of cobalt filters was performed on 17 patients. Eleven patients were subjected only to irradiation of the head.

We obtained fully satisfactory results among almost 2/3 of our patients with acromegaly and adiposogenital dystrophy.

The reduction or elimination of severe symptoms, the restoration of sight, the return of patients in a number of cases to an active life, to work — all these make radiation therapy, along with the individual approach to the patient, an irreplaceable method of treating such grave disorders as acromegaly and adiposogenital dystrophy.

The Central Scientific Research Institute of
Roentgenology and Radiology

THE RESULTS OF THE USE OF RADIOACTIVE PHOSPHORUS IN DERMATOLOGY

K. P. Nartsisova

1. The use of radioactive phosphorus for therapeutic ends presents great possibilities in dermatology.
2. The use of the pure β -radiation of phosphorus enables one to conduct a selective superficial irradiation of the skin without damaging the more deeply located tissues and organs.
3. Much attention has been given to this method both abroad and in the Soviet Union. The initial results of the use of P^{32} have already shown this method to be highly effective in the treatment of eczemas, neurodermatitis, carbuncles and furuncles, tuberculosis cutis and capillary hemangiomas.
4. In the treatment of vascular birth marks we employed the method proposed by A. V. Kozlova, in 1949.
5. We had under observation 145 patients with capillary hemangiomas. Full clinical recovery was observed only among infants; among adults the results of application treatment surpassed those obtained with radium and cryotherapy with respect to cosmetic effect.
6. The experimental use of P^{32} in treating pigmented blotches indicates that no prospects are provided by this method in the given pathological conditions.
7. Good results have been achieved with the therapy of recancerous conditions of the skin and mucosae (according to A. V. Kozlova).
8. The medical practice of the Ukrainian Scientific Research Institute of Dermatology and Venerology provides evidence of the effectiveness of the use of P^{32} in the treatment of eczemas, neurodermatitis, pyodermitis, sycoes, tuberculosis cutis, etc.
9. It is unwise to perform β -therapy on disseminated or recurrent dermatoses, dermatoses with which there exists a marked sensitivity of the organism to radiant energy, and also on those portions of the skin irradiated previously with roentgen or γ -rays.

The Kharkov Scientific Research Institute of
Dermatology and Venerology

β - SOURCES FOR EXTERNAL IRRADIATION IN MEDICINE AND BIOLOGY

V. A. Petrov

At the present time the following means of using β -active substances have been clearly determined:

1. Injection of radioactive substances into an organism.
2. Application—placing β -active sources on the body or introducing them into a cavity.
3. External irradiation, in which the source of β -radiation is at a distance from the surface of the body. In this case, if the predominant part of the body is irradiated, or the entire body, the irradiation is called general or total.

In the present work the injection of radioactive substances into an organism is not considered.

4. Different applicator designs are described: plane, cavity, ocular.

The power of the dose P_A on different portions of tissue for a plate applicator can be determined according to the formula:

$$P_A = 17.7 \cdot C \bar{E}_\beta [\Phi(\mu H) - \Phi(\mu H + \mu L)] \frac{\text{rad}}{\text{min}}$$

where C is the concentration of the radioactive substance of the source (in mc/cm^2);

$\bar{E}_\beta$ is the average energy of β -particles (MeV);

Φ is King's function;

H is the distance from the applicator (in cm);

L is the thickness of the applicator (in cm).

5. The power of the dose of ocular applicators can be determined according to the formula:

$$17.7 \sigma \cdot \bar{E}_\beta \cdot \mu [-E_i(-\mu H) - E_i(-\mu \sqrt{A^2 + H^2})] \frac{\text{rad}}{\text{min}}$$

where σ is the density of activity (mc/cm^2);

μ is the coefficient of linear decay;

A is the radius of the source of radiation (in cm);

H is the distance from the center of the source of radiation (in cm).

6. The power of the dose on the surface of the body from an external source of radiation in the form of a disc may be determined according to the formula:

$$P_1 = 2.8 \cdot \sigma \bar{E}_\beta \psi 2\pi (1 - \cos \theta) \frac{\text{rad}}{\text{min}}$$

where θ is the angle of the opening.

A comparison is made of calculated and experimental data.

The power of the dose in the case of total irradiation when the irradiated body is located within the source of field radiation can be determined according to the formula:

$$P = 2.8 \cdot \sigma \bar{E}_\beta \psi \frac{\text{rad}}{\text{min}}$$

where ψ is the solid angle in which the source of radiation is seen from a point lying on the surface of the body.

A comparison is made between calculated and experimental data.

The Central Scientific Research Institute of
Roentgenology and Radiology

DATA PERTAINING TO A PHYSICAL AND CLINICAL EVALUATION OF THE RADIOGRAPHIC UNITS GUT-Co-20 * AND GUT-Co-400 *

G. F. Nevskaya

1. The results of trial runs and clinical exploitation of the radiographic units GUT-Co-20 * and GUT-Co-400 * are discussed.

2. The merits and defects of the construction of the GUT-Co-20 unit are noted.

The special construction features of the apparatus guarantee generation of a maximal dose of radiation at given depth along with relative protection of the surface of the skin. This situation is confirmed by data on the spatial distribution of the radiation and an analysis of the results of clinical observations.

The negative side of the construction of the unit is the insufficient shielding of the head of the tube, which leads to irradiation of tissues beyond the limits of the field of irradiation. The protection from the radiation of the preparation in the off position is also insufficient.

The possibilities of improving the construction of units of similar type are discussed.

3. The merits and defects of the radiographic unit GUT-Co-400 are discussed.

A study of the spatial distribution of γ -radiation shows the advantage of using the GUT-Co-400 apparatus over a roentgen unit operating on 200 kilovolts (the RUM-3). An analysis of the results of clinical observations confirms this position.

The question of the reasonable magnitude of the activity of the source is discussed.

The Academy of Medical Sciences of the USSR

*GUT-Therapeutic gamma-ray source.

TECHNICO-PHYSICAL STUDIES OF THE ARTIFICIAL RADIOACTIVE ISOTOPE
 Tu 170 AS A GAMMA-RAY SOURCE FOR FLAW INSPECTION AND MEDICAL
 GAMMA-GRAPHY

I. A. Bochar, N. S. Nikitin

1. Because of the presence of soft gamma components in its spectrum, the artificial radioactive isotope Tu 170 is better suited for use in the flaw inspection of light metals and alloys and of small gauge steel than such isotopes as Co 60, Cs 134, and Ir 192.

Tu 170 can also be used for medical gamma-graphy.

2. As well as gamma radiation, the thulium preparation also emits bremsstrahlung radiation of considerable intensity, which originates from the absorption of the thulium beta particles in the preparation. Therefore, the radiation spectrum of thulium fluctuates considerably when the source thickness is changed.

3. Because of the large quantity of bremsstrahlung radiation present, it is stronger than gamma-radiation from thulium, and the weight of protective devices used in work with radioactive thulium somewhat exceeds the weight of similar protections from Ir 192 gamma-radiation with equal source strengths in mg-equiv. Ra.

4. The results obtained from research with a 16.5 curie thulium source led to the conclusion that it was expedient to introduce Tu 170 as a gamma-radiation source for medicine and for industry.

Academy of Medical Sciences, USSR

The above summary appeared on page 85 of the original Russian publication. The summary below appeared on page 91 of the original Russian publication. Pages 86-90 were not available for translation as they were not included in the original Russian publication through a pagination or binding error.

THE ACTION OF PENETRATING RADIATION ON THE BONE MARROW CELLS OF
 ANIMALS STUDIED BY THE METHOD OF LUMINESCENT MICROSCOPY

T. M. Kondratyeva

1. The purpose of this work was the study of the changes (especially the early ones) which occur in the bone marrow cells under the influence of various doses of roentgen rays.

2. Using the luminescent microscopy method, it was possible to trace successively in dynamics, the processes which took place in the cells, after exposure of the organism to radiation which led to the destruction and death of the cells. In some of the cells, these processes began immediately after irradiation and, depending on which substrates were first hit, developed in different ways. The changes began either with the damage of the deoxyribonucleic complex, when they were first manifested by nuclear disturbance, or with the evident disturbance of ribonucleic exchange, when the destructive processes first affected the cytoplasm.

3. The gravity and profundity of cell injuries and the rate of their development depended on the radiation dose. With the action of doses of from 600 to 900 r, the appearance of a considerable number of damaged cells was noted immediately after exposure to radiation. After one hour, the cells with early-stage changes predominated until the nuclear matter disintegrated. During the first day, these changes continued to increase, as did the number of damaged cells. Only on the ninth day did many normally luminescent cells appear.

4. These early stages of cell damage after the action of radiant energy were not detectable on smears or on regular histological preparations from bone marrow, but the use of the luminescent method disclosed them. Using the regular preparations, we and other authors could find only the coarser and later aspects of cell disintegration.

5. Luminescent microscopic study is extremely important as it gives an idea of not simply the morphological changes occurring in the cells, but also, in some degree, the cytochemical disturbances which are the reason and the basis for those morphological changes.

Central Scientific Research Roentgen-Radiology Institute

SOME NEW DATA ON THE NEURO-HUMORAL DEVELOPMENT MECHANISM OF THE
 RADIATION SICKNESS SYNDROME

N. S. Dzhevadyan

The effects of irradiation on sections of the carotid artery of the organism and on the cervical vagosympathetic trunks were studied on 20 dogs.

For this purpose, sections of the carotid arteries and the designated nerves were irradiated in critical experiments after their preliminary injection by a dose of 600-5,000 r into a piece of skin of the neck region in conditions of isolation.

Intravascular irradiation of the blood resulted in a mild form of radiation sickness. When the blood was irradiated by a 5,000 r dose, lowered erythrocytic resistance, increase of free hemoglobin in the blood plasma during the first two days after irradiation, and retardation of blood coagulability were also noted.

It can be considered that blood is more sensitive to ionizing radiation when it has been internally irradiated than when irradiated in vitro. The exposure to radiation of the vagosympathetic trunks caused temporary leukopenia, eosinopenia, an increased quantity of erythrocytes, and an irritation of the red bone marrow.

Central Institute of Hematology and Blood Transfusion

SOME QUESTIONS OF THE PATHOGENESIS OF THE HEMORRHAGIC SYNDROME IN ACUTE RADIATION SICKNESS

N. V. Butomo, K. V. Gordeeva, T. K. Dzharakyan, D. A. Ilyinsky, L. A. Klyucharev,
Z. P. Kovtun, V. I. Kuznetsov, O. K. Makhalova, A. S. Mozzhukhin, A. D. Smirnov,
K. B. Tikhonov, G. F. Fakhruddinov

The hemorrhagic syndrome, one of the most characteristic symptoms of acute radiation sickness, is present during the whole course of the sickness, and in many cases is the cause of death.

At the present moment, the development mechanism of the hemorrhagic syndrome is not clear, and comparatively few works have undertaken its study.

Consequently, neither rational methods to prevent and fight hemorrhages nor means to decrease or relieve the occurrence of the hemorrhagic syndrome exist.

When studying the pathogenesis of the hemorrhagic syndrome in radiation sickness, one must consider the various possible mechanisms of its genesis. Our studies showed the most important moment in the development of this syndrome to be the functional and morphological changes of the blood vessel wall.

1. The heightened tonicity of the muscular type of artery, the lowered tonicity in the small veins and capillaries and the inequality of these relationships in different regions of the body lead to congestion symptoms in the vessels, principally those of the internal organs. The disturbed distribution of tonicity in the blood vessels is probably explained by the functional changes of the central regulating mechanisms, since sharp changes were then observed in conditioned and unconditioned reflexes of the vessel. At the same time, the reaction of body vessels and isolated organs to the injection of histamine, adrenalin, acetylcholine, and pituitrin-S was not significantly changed. The same symptoms were observed during the critical period of the disease.

2. Even in the first stage of the disease, one could observe a heightened permeability and fragility of the cutaneous vessels and those of the limb muscles. These changes were most sharply expressed during the critical period of the disease.

3. At the end of the first period and in the critical period of the disease, destructive changes developed in the arterial and venous vessels (principally in the small veins and capillaries), which were expressed in perivascular edema, endothelial desquamation, broken elastic fibers, homogenization of the muscular layer, etc. All these changes occurred in separate foci, apparently surrounded by unchanged vascular wall. These changes, in conditions of disturbed blood circulation, obviously led in many cases to ruptured vessels and to hemorrhage, as we observed on histological preparations.

Parallel with the wall changes of the blood vessels in the critical period of radiation sickness occurred substantially important disturbances in the blood circulatory system.

1. The number of thrombocytes gradually decreased, indicating depression of the bone marrow function.

2. The prothrombin time was extended due to the depression of the prothrombin formation function of the liver.

3. The quantity and quality of blood plasma fibrinogen changed, and this led to the disruption of the blood circulation process in its final circulus—the transformation of fibrinogen into fibrin.

4. Enumerated changes in the blood circulatory system were observed at the end of the latent period of the disease, when the hemophilia symptom could not yet be clinically observed, and remained through the resolution period, when the hemophilia symptom disappeared. Evidently, blood circulation changes begin to play an important role pathogenetically only when the functional and morphological changes of the blood vessel walls have developed.

S. M. Kirov Order of Lenin Academy of Military Medicine

AGE CHARACTERISTICS OF ACUTE RADIATION SICKNESS COURSE IN CERTAIN TYPES OF LABORATORY ANIMALS

T. V. Fokina

The characteristics of the course of acute radiation sickness relating to different age groups were studied on rabbits and rats which were exposed to radiation at ages varying from the new-born to the completely mature.

A one-time total irradiation with roentgen rays was used in the following doses: minimum lethal, 50% lethal, and in a dose giving a small percentage of death in mature animals of a uniform type. For our growing animals, we used the same dosages, which were, for rabbits, 1,200; 600 and 300 r, and for rats, 1,000; 500 and 250 r.

The work carried out showed that there were both general age characteristics applying to both kinds of animals, and traits characterizing only this or that type of animal.

The most characteristic trait of acute radiation sickness during the first few days after the animals were born (rabbits and rats) was the disturbance of growth and the development of acute dystrophy, with considerable retardation of weight and size increase. At the time of death, after exposure to minimal absolute lethal doses of roentgen rays, the weight deficit in this age group was as much as 40-50 % compared with the control animals, and in adult animals, it was 18-20% of the initial weight of the animals.

Here, severe emaciation was observed in the animals, almost a complete loss of the subcutaneous fatty layer, a sharp decrease of skin turgor, skin dryness, and a decreased size of the internal organs, especially the spleen and the thyroid gland. Other symptoms of acute radiation sickness peculiar to adult animals were loss of appetite, diarrhea, etc., which were negligible in the very young animals.

The course of acute radiation sickness in animals exposed when one to two months old was symptomatically more similar to that in mature animals.

The gravity of the hair integument affection, in both types of animals, depended on the age at the time of irradiation and on the dose of radiation. The gravest hair integument affections, sometimes reaching complete depilation, were observed in animals which were exposed to radiation at the time when they normally would be growing their fur or had just grown it (in rats exposed at ages of from 10 to 25 days, and in rabbits varying from 5 to 25 days of age).

Both kinds of animal developed the gravest leukopenia when they were exposed during the first days of life, as compared with the older age groups.

There were certain differences in rabbits and rats from the standpoint of red blood changes; the dynamics of red blood change after exposure to radiation were essentially the same in the different age groups of baby rabbits as they were in the mature animals, but, in the rats, the greatest injury to the red blood after irradiation appeared in the youngest age group of the animals (exposed the first days after birth).

Institute of Pediatrics,
Academy of Medical Sciences USSR

AGE CHARACTERISTICS OF THE COURSE OF ACUTE RADIATION SICKNESS IN SEVERAL SPECIES OF LABORATORY ANIMALS

T. V. Fokina

The age characteristics of the course of acute radiation sickness were studied in young rabbits and rats, irradiated from the day of birth up to the stage of sexual maturity.

A single total irradiation dose of x-rays was used; minimal lethal dose, 50% lethal dose and a dose giving a small percent of mortality in adult animals of the respective species. We also used these dosages for the growing animals, which were for young rabbits 1200, 600, and 300 r, and for young rats 1000, 500, and 250 r.

The experiments showed that there are age characteristics of the course of acute radiation sickness common to various animal species, and also features characteristic of only certain animal species.

The most typical feature of acute radiation sickness in animals in the first days of life (rabbits and rats) is growth disturbance and development of marked dystrophy with considerable lag in weight and growth. The weight deficit at death following irradiation with minimal completely lethal doses of x-rays reached 40-50% in this age group in comparison with controls, while in adult rabbits and rats it was 18-20% of the initial weight of the animals.

Extreme emaciation of animals was observed here, almost complete loss of the subcutaneous fatty layer, marked lowering of skin turgor, skin dryness, and decrease in dimensions of internal organs, especially spleen and thyroid. Other symptoms of acute radiation sickness, characteristic of adult animals, such as sharp decrease in appetite, diarrhea, etc., were insignificant in animals in the first days of life.

The symptomatology during the course of acute radiation sickness in animals, irradiated at the age of 1-2 months, was more typical of the adult animal.

The severity of the affection of the fur in both animal species depended on the age at the time of irradiation and on the radiation dose. The most severe affections of the fur, up to complete baldness, were observed in animals irradiated at the stage when they are normally growing fur or the fur has just grown (in young rats with irradiation from the 10th to 25th day, in young rabbits from the 5th to 25th day).

In animals of both species, irradiated when a few days old, the development of very severe leucopenia in comparison with older age groups, is typical.

Some differences were found in red blood changes between young rabbits and rats. Thus, while in various age groups of young rabbits the dynamics of red blood changes after irradiation did not differ essentially from that in the adult animals, in rats a very severe effect on the red blood after irradiation was found in the youngest age group (irradiated in the first days after birth).

Institute of Pediatrics, Academy of Medical Sciences
of the USSR

EFFECT OF X-RAYS ON THE COURSE OF PREGNANCY AND FETAL DEVELOPMENT

N. L. Garmashev and P. G. Svetlov

1. The effect of irradiation of the pregnant animal on the course of pregnancy and delivery was studied, as was embryogenesis, the condition of the fetus and the newborn; certain aspects of the mechanism of fetal injury were also examined.

Total single irradiation by x-rays of rats was carried out at different stages of pregnancy, beginning prior to implantation and ending with the predelivery stage. The x-ray dose in most experiments was for rats 200-700 r, for rabbits—250-600 r with filter of 0.5 mm copper and 1.0 mm aluminum. More than 1000 rats and 200 rabbits were studied.

2. The results showed:

The reaction of pregnant animals to irradiation differs somewhat from that of nonpregnant, which is explained both by certain features of pregnancy, for example the changed blood-forming function (N.M. Andriyasheva), and by the aggravating effects related to disturbance of the condition of the fetus, its death and resorption (N. A. Kalinina).

Irradiation at various stages of pregnancy, including early stages, disturbs the course of delivery, which is explained largely by disturbance of mechanisms regulating the delivery process, but not of the contractile properties of the maternal muscles (N. A. Kalinina, Z. N. Zhakhova).

The effect of irradiation of the animal on fetal development varied in relation to the stage of pregnancy at the time of irradiation. There were many dead fetuses with irradiation in early stages of pregnancy, beginning at the first day; then the curve falls. The number of abnormal fetuses, on the contrary, is small with irradiation in early stages of pregnancy; then the curve rises, reaching a maximum by the 12th day of pregnancy. With irradiation of the rat on the 10th day of pregnancy abnormalities of development of the brain predominate, on the 11th—of the eyes and maxillary apparatus, on the 14th—of the extremities (P. G. Svetlov and G. F. Korsakova).

Study of development of the newborn and their blood changes showed that in pregnant animals, irradiated in the earliest stages of pregnancy and suffering from radiation sickness of medium severity, birth of viable young is possible (N. M. Andriyasheva, N. A. Kalinina).

Results of various experimental studies provide a basis for considering that in the mechanism of fetal injury upon irradiation of the animal at all stages of pregnancy both the direct effect of penetrating radiation on the fetus (the character of this effect changes considerably with fetal development) is of significance, as well as the change in state of the maternal organism produced by irradiation.

Institute of Obstetrics and Gynecology, Academy
of Medical Sciences of the USSR

EFFECT OF IONIZING RADIATIONS ON OFFSPRING UPON IRRADIATION OF ANIMALS IN TERMINAL STAGES OF PREGNANCY

E. A. Zuikova, M. Ya. Chaikovskaya and S. L. Petrosyan

1. The question of the effect of ionizing radiation on offspring of mothers receiving total irradiation in the terminal stages of pregnancy is inadequately covered in the available literature.
2. In our experiments the effect was studied of radiation energy on puppies born of mothers irradiated in the last days of pregnancy.
3. Observations on puppies born of mothers irradiated in the last days of pregnancy showed that most of them were not capable of survival.
4. Total irradiation with sublethal doses of dogs in the terminal stages of pregnancy leads to development of acute radiation sickness of the newborn pups.
5. Duration of life of the newborn affected with radiation sickness is in direct relation to the radiation dose given their mothers during pregnancy.
6. In newborn puppies with radiation sickness profound morphological changes develop in both tissue and membranes of the brain.
7. The frequently observed congenital atelectasis of the lung in the newborn is related to the poor viability and underdevelopment of puppies born of irradiated mothers.
8. In our experiments radiation sickness of the newborn terminated fatally in a large percent.
9. The autopsy picture of the newborn is essentially similar to that in adults dying of acute radiation sickness.
10. In contrast to adult animals in which radiation sickness occurs not infrequently with complications localized chiefly in organs of the gastrointestinal tract and lungs, in the newborn it is accompanied by profound changes in the urinary bladder.
11. Mothers, irradiated during pregnancy, were more resistant to ionizing radiation than their newborn. Their radiation sickness was mild, the blood reaction to the radiation was of a temporary and characteristic type.

V. M. Molotov State Research Institute of Roentgenology and Radiology

ABNORMALITIES OF DEVELOPMENT IN OFFSPRING OF ANIMALS IRRADIATED BY γ -RAYS AND THEIR INHERITANCE IN SEVERAL GENERATIONS

A. I. Osipovsky

As is known, the effect of irradiation of parents on development of offspring is of great theoretical and practical significance.

Careful experiments are necessary to clarify the question — can irradiation of the organism leave traces in its descendants in the form of certain deviations from the normal course of ontogenesis?

There is a considerable literature in which it is shown that upon irradiation of invertebrates and plants, abnormalities of development are consistently observed in a certain percent of cases.

Experiments on mammals are not numerous.

We subjected sexually mature rats to single irradiation by γ -rays, seven days before interbreeding, with doses of 198, 360 and 520 r. In all we followed about 800 descendants in three generations from irradiated animals suffering from acute radiation sickness. Among the descendants abnormalities of development were found: in the skeleton, teeth, fur, general underdevelopment (dwarfism), vestibular apparatus, genital organs, etc.

DIAGRAM OF INTERBREEDING OF PARENT ANIMALS

- 1) nonirradiated males and females were interbred;
- 2) nonirradiated males and irradiated females were interbred;
- 3) irradiated males and nonirradiated females were interbred;
- 4) males and females irradiated by γ -rays in dose of 198 r were interbred;
- 5) males and females irradiated by γ -rays in dose of 360 r were interbred;
- 6) males irradiated by γ -rays in dose of 520 r and females in dose of 360 r were interbred.

With the exception of the control, abnormalities of development were found in all the interbred groups indicated.

First Moscow Order of Lenin Sechenov Institute of Medicine

EFFECT OF X-RAY IRRADIATION ON NATURAL RESISTANCE OF ANIMALS TO VIRUS INFECTIONS

O. P. Peterson, I. A. Kozlova and E. I. Sklyanskaya

In this report the results are shown of experiments on the effect of x-ray irradiation on natural resistance of animals to the viruses of grippé, yellow fever and encephalomyocarditis. A difference was found in the effect of x-ray irradiation on natural resistance of animals to the grippé virus and to the neurotropic viruses: yellow fever and encephalomyocarditis. In the first case a sharp decrease in natural resistance is observed, in the second — a quite considerable stability of the organism.

The dynamics of multiplication of the grippé virus was studied in organs and tissues of irradiated guinea pigs, killed at different times after infection. Here it was shown that maximum multiplication of the grippé virus occurs in lung tissue of guinea pigs, killed on the third and fourth day after infection. The amount of virus in this tissue decreases by the 6th, 7th and 8th days, and 10 and 20 days after infection the grippé virus cannot be isolated from lungs of guinea pigs. It should also be noted that, beginning at the 4-5th day and to the end of the experiment (i.e., to the 20th day) after infection in irradiated guinea pigs the grippé virus is found in the liver and spleen. In control pigs (infected without previous irradiation) the virus was not once isolated from a single organ. Nor was the virus isolated from the blood of experimental or control animals.

The results obtained show that x-ray irradiation sharply affects the guinea pig, as a result of which a natural resistance to the grippé virus appears, and a developing grippé pneumonia not infrequently leads to death.

Pathogenesis of the grippé infection here does not differ essentially from the disease in white mice, which are highly susceptible to grippé.

The finding of the grippé virus in liver and spleen is apparently related to the increased permeability of tissues and vessels, observed in radiation sickness. There is no indication of multiplication of the virus in these organs, since it was isolated from liver and spleen of mice and embryos (infected by suspensions of liver and spleen) in low titers.

Results of experiments with yellow fever virus showed that preliminary and subsequent irradiation in doses of 100 — 500 r, administered 2, 7 and 12 days before infection, did not lower resistance of white mice to this virus upon subcutaneous, intraabdominal and intranasal infection and did not increase sensitivity to intracerebral infection.

However, in mice irradiated two days after infection with encephalomyocarditis virus (strain "MM"), increased susceptibility to subcutaneous infection with this virus was observed.

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of the USSR

DATA ON THE COURSE OF EXPERIMENTAL GRIPPE IN MICE SUBJECTED TO IONIZING RADIATION

V. P. Emalkina and O. P. Lebedeva

1. The problem of the present paper is clarification by means of microbiological and morphological studies of certain features of the course of experimental grippé and development of autoinfection in irradiated mice.

2. Irradiated and infected animals, as well as animals in the control groups, were killed at intervals in the course of 21 days; bacteriological and histological studies were made, and the titer of grippé antibodies was determined.

3. In bacteriological study of the lungs in mice irradiated and infected with grippé various microorganisms were found, 2 — 3 — 4 species of the usual pathogens in each case: streptococci, staphylococci, rods of the paracoli group, and rods of the diphtheroid type.

In the control group of irradiated animals a similar harvest of the usual pathogenic flora was found, represented by one or two microbial species.

In animals infected with grippé, infiltration of the lungs by the usual pathogens was found in only half the cases, only one species of the microorganisms mentioned above being found.

4. In animals irradiated and infected by grippé, as well as in the control group of irradiated animals, the usual pathogens were systematically found in the blood.

In mice infected with grippé, bacteremia was found in only half the cases.

5. In contrast to mice of the control group, infected with grippé, in which we consistently found grippé antibodies, in animals irradiated and infected with grippé, antibodies were not found in the course of 21 days of observation.

6. In animals irradiated and infected with grippé severe affections of the lungs were found in histological study twice as frequently as in the control group of mice infected with grippé.

7. The inflammatory process, produced by grippé in lungs of irradiated mice, remains for a long time in the acute or subacute stage, showing no tendency to effective resolution, and proceeds on a background of marked disturbances of blood circulation.

8. The more diverse and more frequently encountered infiltration of lung tissue and blood in irradiated and infected mice, as well as the absence in these animals of grippé antibodies can, together with other causes, explain the prolongation of the course of grippé pneumonia combined with radiation sickness.

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THE COURSE AND TREATMENT OF EXPERIMENTAL PNEUMONIA IN RADIATION SICKNESS

P. N. Kiselev, R. M. Rabinovich and I. D. Meter

In the organism subjected to the total action of sublethal and lethal doses of ionizing radiation, the natural immunity is markedly disturbed and various infectious and autoinfectious processes arise, which are one of the chief causes of the fatal outcome in radiation sickness.

Among autoinfections complicating radiation sickness, pneumonia occupies a prominent place (50%).

In view of this it is of much interest to study the special features of the development, course, outcome and treatment of pneumonia in radiation sickness.

In this study, carried out on 72 rabbits and 160 rats, experimental staphylococcus pneumonia was studied after x-ray irradiation of animals in doses of 200 - 700 r. The investigation was conducted by clinical x-ray, microbiological and pathohistological methods.

The results of these studies established:

1. Inoculation of animals, irradiated by the indicated x-ray dose, led to development of pneumonia which was absent in the control. Pneumonia is readily revealed by x-ray at an early stage of development. The inflammatory and necrotic changes of the lung tissue serve as the anatomical substrate of these changes.

During development of pneumonia, leucocytosis is also observed, which in contrast to normal animals, develops on a background of leucopenia. The pneumonia without treatment terminates fatally.

2. Bacteriological studies show the pronounced multiplication of microorganisms in lung tissue, bacteremia, and development of sepsis to be the chief cause of the fatal outcome of pneumonia in radiation sickness, and disappearance of microorganisms from the lungs is slower than in the control.

3. At the basis of the violent development of pneumonia in radiation sickness lies the general weakening of the organism's immunity and defense reaction of the lung tissue, shown in suppression of the inflammatory reaction and predominance of necrosis over inflammation.

4. The treatment of the experimental pneumonia with antibiotics that we used proved quite effective. Some failures in treatment of pneumonia with antibiotics are related to development of bacterial strains resistant to the antibiotics. This indicates the necessity of using combined antibacterial and chemotherapeutic treatment of pneumonia in radiation sickness.

Central Research Institute of Roentgenology and Radiology

ANAEROBIC INFECTIONS, THEIR PROPHYLAXIS AND THERAPY IN ANIMALS SUBJECTED TO PENETRATING RADIATIONS

R. V. Petrov

1. White mice irradiated by γ -rays develop increased sensitivity to infection by microorganisms of gas gangrene and tetanus. Maximal sensitivity to *Bacterium perfringens* is observed upon infection for five days after irradiation. Normalization of sensitivity occurs in 15 - 17 days.

2. Experimental gas gangrene, developing after infection of guinea pigs in the opening of a skin-muscle cut, is considerably more severe in animals irradiated by x-rays and γ -rays.

3. Therapeutic use of antitoxin serum or penicillin in experimental gas gangrene, developing at an early stage after irradiation, is less effective in irradiated animals than in normals. Combination of serum and penicillin is equally effective in the gas gangrene of experimental and control animals.

4. Upon infection of guinea pigs in the early stages after irradiation, serum prophylaxis of gas gangrene with antitoxin serum is just as effective as in normal animals.

5. Serum prophylaxis of tetanus in irradiated white mice is less effective than in normals upon infection 10 hours after irradiation. To obtain an equivalent effect administration of a triple dose of serum is required.

6. The mechanisms of immunity, including passive immunity, are not injured at once after irradiation. In the course of the first two days there is compensation of the developing disturbances. From the third day there occurs marked depression of natural and artificial immunity.

Academy of Medical Sciences of the USSR

EFFECTIVENESS OF REVACCINATION AGAINST TYPHOID INFECTION IN IRRADIATED ANIMALS

M. A. Tumanyan and A. V. Izvekova

It is known that irradiation, performed after immunization, reduces nonsusceptibility of animals to infection. At the same time, during study of the action of ionizing radiation on immunity to intestinal infections, we obtained data (1956) on the fact that vaccination of irradiated animals is feasible and effective under certain conditions. These data, however, did not answer the question: does the immunological reactivity of the organism change under the action of irradiation, in other words, does there remain in the organism subjected to irradiation a certain state of immunological reorganization from immunization preceding irradiation?

To answer this question standard typhoid infection in white mice was used. The mice were three times immunized with typhoid formol vaccine, and 10 days after completion of immunization were irradiated by a dose of 250 r with apparatus RUM-3 (irradiation conditions: 180 kv, 15 ma, filters 0.5 mm Cu and 1.0 mm Al, dose in atmosphere of irradiation field 43 t/min. A dose of 250 r produced up to 25% mortality of mice in 30 days. Ten days after irradiation the animals were subjected to revaccination once or three times. Determination of immunity was conducted by means of intraabdominal infection of mice with a live culture of typhoid bacilli a week after completion of revaccination.

The experiments showed that revaccination (once as well as three times), performed soon after irradiation, produces in irradiated animals a well marked immunity, no less intense than the immunity of revaccinated nonirradiated animals. This effect of revaccination in the irradiated organism can be explained only by the fact that the original immunization, conducted prior to irradiation, produced immunological reorganization of the organism, which was retained after irradiation, despite the fact that irradiation practically removed the state of immunity in the immunized animals.

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EFFECT OF IONIZING RADIATION ON DEVELOPMENT OF IMMUNITY UPON REVACCINATION

A. V. Ponomarev

In the pathogenesis of infections and in the immunity to them, the reactivity of the organism has a leading role, which, as is known, changes under the influence of various factors of the external environment.

One such powerful factor is ionizing radiation, producing in animals and man a number of severe pathological processes.

Guided by these considerations, experimental studies were conducted on the influence of ionizing radiation, on the one hand, on the course of the infectious process (experiments of L. Ya. Ebert), and on the other, on the development of immunity in primary immunization and also in revaccination (experiments of L. A. Shabarov).

The following conclusions can be made from the studies:

1. Under the action of ionizing radiation there occurs a reduction of both the organism's natural resistance to infection and its immunological reactivity.
2. Irradiation of animals produces depression of the organisms defense reactions and seriously aggravates the course of experimental infection, which acquires a generalized character, and rapidly leads to death.
3. At the moment of exacerbation of the radiation sickness, produced by irradiation of animals two days after completion of vaccination, there is noted a sharp reduction in intensity of antitoxic immunity (to tetanus) and antibacterial immunity (to typhoid).
4. At the stage of development of symptoms of radiation sickness there occurs a certain re-establishment of the vaccination immunity, although its intensity still does not reach the degree characteristic of immunized nonirradiated animals.
5. The action of irradiation on immunogenesis depends on the stage of its application. Sharp depression in production of antitoxic and antibacterial immune bodies is observed under the conditions of previous irradiation of animals prior to administration of antigens.

6. Under the action of ionizing radiation there occurs sharp reduction in the immunological reactivity of the organism, which develops as a result of the primary vaccination.

Therefore, revaccination may prove ineffective in the organism subjected to ionizing radiation.

7. The immunological reactivity of the organism is fully restored at a certain time after irradiation (3-3½ months in rabbits). Therefore, after recovery from radiation sickness revaccination again becomes effective.

8. These data must be taken into account in carrying out specific prophylaxis under conditions of infection by ionizing radiation.

9. Experimental study of the course of infection and development of immunity after subjection of the organism to ionizing radiation points the way to prophylaxis and therapy of infectious complications in radiation sickness.

Kirov Order of Lenin Academy of Military Medicine

SOME IMMUNOLOGICAL MECHANISMS OF SELF-DEFENCE OF THE ORGANISM AGAINST THE ACTION OF IONIZING RADIATION

P. N. Kiselev and V. A. Semina

For rational prophylaxis and therapy of radiation damage a detailed knowledge is necessary of the mechanisms of self-defense of the organism against the injurious action of radiation. There are two methods of studying the means of the organism's self-defense against the damaging action of radiation - the analysis of natural and of artificially acquired radioresistance.

On the basis of the leading role of autoinfection and autointoxication in the outcome of radiation sickness, immunological analysis was made of the artificial radioresistance of white mice, produced by previous irradiation of animals with sublethal doses of x-rays.

This study clarified a number of important points, making possible an explanation from the immunological point of view of certain mechanisms of the organism's self-defense, which lie at the basis of artificially acquired radioresistance.

On the basis of the experimental data obtained a number of statements can be made:

1. The previous action on the organism of ionizing radiation in doses which do not markedly suppress immunogenesis, leads in 2-3 weeks after irradiation to increase in radioresistance, expressed in the 1½-2-fold decrease in lethal effect in comparison with the control. Doses of radiation which suppress immunogenesis, do not cause development of radioresistance.
- The optimal stages of development of radioresistance depend on the size of the radiation dose and are related to the process of repair and hyperregeneration of the tissues in response to radiation damage.
2. The radioresistance of the organism, produced by previous irradiation by sublethal doses of x-rays, is not specific. Radioresistant animals are more resistant to microbial toxins (*B. perfringens*, *B. dysenteriae* Shiga). The lethal effect on the previously irradiated animals of the indicated toxins in contrast to animals with acute radiation sickness is reduced (for *B. perfringens* toxin 1.7 times and Shiga dysentery toxin 1.25 times).
3. In artificially radioresistant animals a lighter course of autoinfection and less intense bacteremia is observed. Previously irradiated animals are two to three times more resistant to infection by auto-strains of *B. coli*.

4. The development of radioresistance is in direct relation to the presence and level of formation of antibodies to the normal body flora and to the tissues' own denatured protein.

5. One cause of artificial radioresistance of the organism, related to previous action of small doses of radiation, is the intensified accumulation in the tissues of the basic intercellular substance of connective tissue, which plays an essential role in the decrease of toxicosis and development of autoinfection.

6. The indicated mechanisms of immunological self-defense of the organism against the action of ionizing radiation, obtained by single irradiation with x-rays, retain their significance also in the chronic action of small doses of the γ -rays of Co^{60} . However, each of these mechanisms comes into action at different periods from the beginning of irradiation.

Central Research Institute of Roentgenology and Radiology

CERTAIN DATA ON EXPERIMENTAL THERAPY IN RADIATION SICKNESS

O. A. Bogomolets, A. S. Boiko, Z. D. Zekhova, V. Ya. Lavrik and G. A. Levchuk

In this work on models of acute radiation sickness induced by the action of large doses of x-rays (doses varying from LD 50 to LD 100) in dogs, rabbits, mice and rats, a study was made of the therapeutic efficacy of various agents and methods of treatment applied individually and in different combinations.

Attaching great significance to the reactivity state of the irradiated organism, the authors employed small doses of andreticular cytoxic serum (ACS) as prepared by Academician A. A. Bogomolets, transfusion of citrated, cationic and alcohol-glucose-citrate blood and administration of vitamin B₁₂ and antibiotics.

The results of the experiments were evaluated by comparison of the clinical pictures of the course of radiation disease in the experimental and control animals, by changes in the coefficient of the trypan blue skin test, by the peripheral blood picture and also by changes in alkali reserve and in the correlations of the serum albumin fractions, by the phagocytic activity of the leucocytes and by the findings of pathomorphological investigations.

In addition, screening of the liver and spleen and surgical removal of the latter were performed experimentally, and in individual cases an Eck-Pavlov vascular fistula was supplied.

The investigations conducted showed that use of ACS alone in very small doses, and also as one of the components in complex therapy, contributes to mitigation of the clinical picture of acute radiation sickness.

In the experiments with the use of various types of blood the best results were obtained with transfusion of cationic and alcohol-glucose-citrate blood, which demonstrate their value in clinical treatment of radiation pathology in combination with other methods of treatment.

In injury by ionizing radiation it is necessary to pay serious attention to the state of reactivity of the organism. One should not forget in this connection the function of the connective tissue system, which plays an important role in the clinical development of the acute radiation syndrome.

Ukraine Chemical Hygiene Scientific-Research Institute

EXPERIMENTAL PROPHYLAXIS AND THERAPY IN RADIATION SICKNESS INDUCED BY EXTERNAL AND INTERNAL RADIATION

A. A. Gorodetski, O. A. Khomutovski and E. Z. Ryabova

1. For the purpose of radiation sickness prophylaxis, tests were conducted on new preparations of the arylthiocarbamide group synthesized in the Organic Chemistry Institute of the Academy of Sciences of the Ukrainian SSR.

Of the 15 tested preparations, the most effective proved to be preparations No. 9 and 12.

Prophylactic administration of these preparations in rats one hour before roentgen radiation at a dosage of 600 r, at which dosage death of the animals reaches 95% by the 30th day, increased the survival rate of the rats by 45-55%. The use of the preparations at other times, both before and after radiation, was not effective.

2. As the work of several authors (A.I. Smirnova-Zamkova, A. A. Gorodetskiy) has shown, with radiation disease induced by incorporated P^{32} , the mesenchymal type tissues are subject to a high degree of change.

A specific agent by means of which one can exert a stimulating influence on mesenchymal tissue is antireticular cytotoxic serum (ACS), suggested by Acad. A. A. Bogomolts.

We studied the effect of ACS on the course of acute radiation disease induced by incorporated P^{32} .

It was found that ACS therapy in this case increases the survival rate of animals by 54% as compared with the controls.

ACS therapy is particularly effective in relation to the hemorrhagic syndrome, which was expressed in animals of the experimental group much more weakly than in the control animals.

3. Therapy of radiation damage induced by incorporated radioactive isotopes not only implies stimulation of the suppressed functions, but also acceleration of excretion from the organism of the radioactive substances.

As the work of T. P. Sivachenko has shown, a 25% increase in excretion of P^{32} from the rat organism by means of saturating the organism with nonradioactive phosphorus increases the survival rate of the animals by 50-60% after administration of lethal doses of P^{32} . In our earlier papers it was established that it is possible to raise excretion of P^{32} from the organism by administration of a combination of parathyroecrine, campolone, and sodium citrate. In the literature there are references to the favorable influence of egg yolk-milk diet and adsorbents on the course of S^{35} -induced radiation sickness. We checked the efficacy of a combination of parathyroecrine, campolone and sodium citrate introduced two hours after intraperitoneal administration of lethal doses of P^{32} . No appreciable difference in the course of acute radiation sickness in the experimental and control groups was observed. Administration of a combination of these preparations and also use of a special diet (milk, sugar, eggs and adsorbents) proved to have little effect on the course of chronic radiation sickness induced by intraperitoneal injections of $0.5 \mu\text{C } S^{35}Cl_2$ body weight. The times at which the animals died, the blood picture, and the number of neoplasms induced differed little between the experimental and control groups.

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CYSTEINAMINE IN THE PROPHYLAXIS OF RADIATION SICKNESS IN MONKEYS

L. F. Semenov

With the object of elucidating the defense role of cysteinamine in the action of ionizing radiation, experiments were conducted on monkeys. Radiation sickness in these animals was induced by single x-ray radiation at doses varying from 700-750 to 800-950 r.

For prophylactic purposes a 10% solution of cysteinamine hydrochloride was introduced intraperitoneally or intravenously 10-15 min. before irradiation at the rate of 150-200 mg/kg.

The preliminary material showed that the prophylactic use of cysteinamine weakens the course of radiation sickness in monkeys, lengthens the duration of life of the animals, and increases the percentage survival rate at lethal radiation doses. At doses exceeding the minimum absolute lethal dose the defense action of cysteinamine was not manifest.

Sukhum Medico-Biological Station of the Academy of
Medical Sciences of the USSR

CLINICAL AND EXPERIMENTAL INFLUENCE OF CERTAIN PREPARATIONS ON HEMATOLOGICAL AND BIOCHEMICAL BLOOD INDICES IN RADIATION SICKNESS

E. A. Abaturova, Z. F. Lopatinkova and A. V. Shubina

The effect of certain preparations on the organism of healthy and radiation-diseased animals was studied. The experiments were accompanied by hematological and biochemical blood investigations.

It was found that Mercamin introduced intramuscularly in rats at the rate of 150 mg/kg 30 min before total irradiation at a dose of 1200 r saved 1/3 of the total number of experimental animals from death. In the course of the first and second hours after its administration, acute acidosis and coagulation of the rat blood was observed.

Aminasin in the same experimental conditions increased the mortality rate of the animals by intensifying the oxidative processes in them.

Upon total irradiation of rats and dogs with lethal doses, Leicogen exerted a good therapeutic effect; fall in animal mortality rate and a favorable effect on the morphological blood picture (prevention of anemia, reduced fall in number of leucocytes and this at later stages than in the control animals).

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DEFENSE ROLE OF CHOLINE IN RADIATION SICKNESS

M. P. Elezarova

In the search for new substances possessing a defense action in radiation sickness we based ourselves on the experimental data obtained by us on the sharp decline in the methylation processes in the tissues after radiation, expressed in a fall in the choline content, with fatty infiltration of the liver, kidneys, and also signs of hemorrhage in the latter. With the aim of protecting the tissues from such damage, it is necessary to supply them with chemical substances with labile methyl groups, such as choline.

We employed choline chloride at a dose of 50 mg per 100 g animal weight, introducing it into rats together with the food for a period of 75 days. A single administration of choline proved ineffective. A total of 400 white rats weighing 180-200 g were used in the experiment. The choline content was determined in the blood, brain, lungs, cardiac muscle, spleen, intestines, kidneys, skeletal muscle and skin immediately after radiation, within 24 hours, and at 3-7-10-20 and 25-30-50-100 and 150 days. It was found that in the white

rats saturated with choline, following irradiation with a dose of 700 and 1000 r, mild radiation disease was present.

On analysis of the data obtained, the defense role of choline in radiation disease was made clear. Thus, at a dose of 700 r 100% survival rate of the animals was observed, at a dose of 1000 r only 2% died, while in the control animals, after irradiation with a dose of 1000 r and further irradiation within one month with a dose of 700 r, 86% survived. Radiation sickness in them developed in the mild form.

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TREATMENT OF RADIATION SICKNESS BY DETOXICATING LIQUID

F. Ya. Sokolov, F. G. Mukhtarova and N. M. Ogloblina

In order to treat radiation sickness, detoxicating liquid (F. Ya. Sokolov) having the properties of neutralizing the toxic products of decomposition, with subsequent excretion of them from the organism, has been proposed.

The liquid is not toxic or pyrogenic. One of the components of the liquid is glucuronic acid which, by combining with the toxic products of decomposition, detoxicates them, thus being converted into a conjugated glucuronic acid. The experiments were performed by us in vitro by means of combining glucuronic acid with the products of albumin breakdown, decomposition products, products excreted in anaerobic infections, with the plasma of irradiated animals and with other products, as well as in vivo on the experimental animals.

For the purpose of testing the therapeutic effect of the liquid proposed, treatment of the experimental animals (rabbits) subjected to ionizing irradiation was conducted. In some cases we induced an acute radiation syndrome and in others a chronic disease.

The general state of the animals, the state of the cutaneous integuments, the morphological composition of the peripheral blood, the myelogram, and histological investigation of certain organs of the experimental and control animals served as indicators of the therapeutic effect of the detoxicating liquid.

On the basis of our observations the detoxicating liquid normalizes the state of the peripheral blood and blood formation in the bone marrow, and also protects the animal organism from serious pathoanatomical changes caused by ionizing radiation.

The detoxicating liquid suggested may be obtained both as a solution and in the dried form.

Uzbekistan Scientific-Research Blood Transfusion
Institute

TRIALS ON THERAPY WITH VITREOUS BODY IN ACUTE RADIATION SICKNESS

Z. T. Belugina

An attempt was made to influence the course and outcome of acute radiation sickness by introducing into the animal organism the vitreous body of the eye (VB) as a carrier of hyaluronic acid.

The experiments were conducted on 85 guinea pigs. The doses of x-rays used: for 23 pigs-350 r, for 62 pigs-500 r; the 500 r dose proved to be lethal for all control pigs. Various medicinal dosages of "VB", introduced in divided doses for the first 7-20 days of the disease, were tested, and the optimal times of introduction of "VB" (7-8 days) and its optimal amount (32 ml at an x-ray dose of 350 r and 40-50 ml at a dose of 500 r) were established.

The results of the trials showed that, in acute radiation sickness, introduction of the vitreous body has a definite medicinal effect. The effect was manifest in a milder course of the radiation damage in the experimental animals than in the controls, in a decrease in quantity and diffusion of hemorrhages in their internal organs and a much quicker restoration of loss in body weight and, finally, in an increase in the survival rate of the pigs receiving specific doses of the vitreous body at short intervals.

In order to clarify the medicinal role of the hyaluronic acid content of the vitreous body, comparative observations were made on pigs irradiated with a dose of 500 r, with administration of divided doses of "VB" and of purified hyaluronic acid. The latter was isolated from the umbilical cord according to the method of Mackline (a preparation combined with albumin) and by the method of S. S. Kostenko (an albumin free preparation) and introduced at a volume of 10 ml in the first two days after irradiation. It was seen that use of hyaluronic acid ensures the same, if not a greater, survival rate in guinea pigs, as with use of "VB" containing an equivalent amount of hyaluronic acid: of 32 guinea pigs irradiated with a dose of 500 r and receiving an injection of "VB" 12 pigs survived; of 10 guinea pigs receiving injections of hyaluronic acid 5 survived.

In the period of observations on the animals irradiated by lethal doses of x-rays (500 r) dynamic investigations of the morphological composition of the peripheral blood, coagulating capacity of whole blood, and the resistance of the skin capillaries were conducted. It follows from the data obtained, that hyaluronic acid and the vitreous body do not possess a direct stimulating influence on blood formation, in particular on thrombocytopenia, do not prevent and do not remove disturbances in blood coagulating capacity and skin capillary resistance due to radiation disease; apparently diminution of hemorrhages in the irradiated guinea pigs upon introduction of "VB" and hyaluronic acid may be explained only by the positive influence of these substances on disturbances in tissue permeability.

The more premature development in the number of leucocytes, the considerably smaller loss in weight and swifter restoration of weight in the experimental animals, noted in the experiments, suggests that the reparative processes in these animals commence earlier and develop more briskly than in the controls.

Central Roentgen-Radiological Scientific Research
Institute

CLASSIFICATION OF ANTIRADIATION AGENTS ON THE BASIS OF COMPARATIVE TESTS

N. V. Luchnik

1. Many antiradiation agents are known, i.e., agents reducing the harmful biological effect of radiations. Further, knowledge on the mechanism of action of radiations in the organism leads one to believe that the mitigation of radiation disease may take varied courses which lends importance to the task of systematization of known antiradiation agents in conformity with the difference in the course of the disease.

2. Mortality of irradiated mammals is unevenly distributed in time and gives a number of "peaks" which are sometimes evident even without special treatment of the results. If one considers the relation between the mortality and survival rate of the animals, then mortality peaks are distinguishable in all experiments.

3. For 30 days after irradiation one may distinguish five mortality peaks. For the various species and breeds of animals and also for various conditions of irradiation similar, but not identical, pictures are obtained.

4. Experiments in the testing of 80 antiradiation agents with use of white mice irradiated with a dose of 1000 r γ -rays in the range of the first two peaks showed that the various agents have a different effect on the mortality distribution: 8 agents reduced the first peak, 11 the second and 11 both peaks; the other substances apparently exert an influence on later peaks or their effect is slight for at a high dose they had no effect.

5. In extensive experiments with radiation doses of 500-700 r the influence of the sex of the animals and of the potency of the dose of eight antiradiation agents on the mortality peaks was studied. Here too the differentiated effect of the various factors on the individual peaks was noted. Thus, introduction of cysteine (before irradiation) or estrogens (10 days after) reduced all peaks more or less equally; spaced radiations reduce mortality in the early stages, atropine (before or after radiation) in the late stages and yeast extract (after irradiation) in the intermediate stages.

6. In the light of the data obtained, the mortality peaks are considered as a reflection of the various ultimate causes of the death of the irradiated animals.

7. Proposed phenomenological classification of antiradiation agents is based on two indices: the time when the agent must be applied in order to achieve the effect, and the relationship of the agent to the mortality peaks.

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CHARACTERISTICS OF DISTRIBUTION AND BIOLOGICAL EFFECT OF RADIOACTIVE ISOTOPES

Yu. I. Moskalev

An analysis was made of the characteristics of distribution and biological action of radioactive isotopes in relation to the path of entry (intravenous, intraperitoneal, subcutaneous, oral), the physiological state of the organism (age, sex, species of animal) and physicochemical factors (isotopic and nonisotopic carriers, pH of original solution, complex forming substances). A description is given of the specific nature of the reactions of the organism in disease by acute, subacute and chronically effective doses of radioactive isotopes having a different character of distribution, appearance, radiation energy and half life.

It was established that there is much in common in the distribution of the elements belonging to the same group of the Mendeleev periodic system. One may distinguish four nominal types of distribution: "skeletal", "hepatic", "uniform" and "renal".

The complex-forming substances, the isotopic and nonisotopic carriers, and the pH of the original solution change the type of distribution of the hydrolyzable elements and do not influence the type of distribution of the highly water-soluble elements. The cations forming at body pH poorly soluble colloidal compounds, on parenteral introduction are chiefly secreted by the feces, while the elements forming negatively charged complexes in aqueous solutions are almost exclusively excreted in the urine. Filtration of many elements through the kidneys depends largely not on particle size but on charge.

Other conditions being equal, the biological effect is determined not by the number of disintegrations, but by the value of the ionization dose generated by the emitter in the animal tissues. The effectiveness of α and β emitters depends on the microgeometry of the distribution of radiation in the tissues.

It was established that the biological effect of emitters (Cs^{137} , Ru^{106} , Nb^{95} , Po^{210} , Sr^{90} , Ba^{140} , Ra^{226} , Pu^{239} , Y^{90} , Ce^{144} , La^{140} , Pm^{147}) can be determined by the physical (dose, speed of radioactive disintegration, hardness and type of radiation) and the "physiological" (type of distribution, routes and speed of excretion, degree of resorption from the depot) properties of the radioactive isotopes and the individual and species radiosensitivity. The type of pathological process does not depend on the form of the radiation.

Characteristic of damage by uniformly distributed emitters (Cs^{137} , Ru^{106} , Nb^{95} , Po^{210}) is atrophy of the spleen and testicles, suppression of lymphoid-blood formation and emergence of tumors of the soft parts. Characteristic of damage by "skeletal" emitters (Sr^{90} , Ba^{140} , Ra^{226} , Y^{90} , Y^{91}) is ectopic splenic blood formation, comparatively strong suppression of myeloid blood formation and emergence of bone tumors; "hepatic elements" (Ce^{144} , La^{140} , Pm^{147}) cause necrotic ulcerous lesions of the intestines with selective localization of the necroses in the proximal sections of the duodenum, pyloric section of the stomach, cyrthosis, hepatic tumors and osteosarcoma.

Emitters having a short half life (La^{140} , Ba^{140} , Y^{90} , Nb^{95} , Cs^{137}) are less toxic than emitters with a long half life (Sr^{90} , Sr^{90} , Ce^{144} , Pm^{147}).

Academy of Medical Sciences of the USSR

TOXICOLOGY OF Co⁶⁰

E. B. Kurlyanskaya, A. A. Rubanovskaya, N. L. Beloborodova, G. A. Avrunina,
E. D. Grishenko, N. I. Vinogradova, E. K. Redkina, A. O. Saitanov,
and I. N. Golovshikova

The chronic effect of Co⁶⁰ on rabbits and rats was studied on daily oral administration at a dose of 1.65 and 16.5 μ C/kg for a period of 21-22 months. These amounts, after onset of equilibrium, generated a mean dose of γ -radiation in the body of 0.44-1.62 r daily and of 1.3-4.7 r daily in the abdominal cavity. The control animals received stable cobalt. We studied: 1) absorption, distribution and excretion of Co⁶⁰ at various stages of administration; 2) the general state of the animals; 3) change in blood formation system; 4) the electrocardiographic shifts; 5) changes in permeability of the eye and skin vessels; 6) certain indices of albumin and carbohydrate metabolism; 7) the pathomorphological changes; 8) tissue dosimetry was performed. All the investigations were conducted in the same animals.

The investigations established the characteristics of absorption of radiocobalt (about 25% of that introduced was absorbed in the gastrointestinal tract), distribution (from 10 to 35% in the liver with roughly uniform specific activity in other organs) and excretion (biological and effective periods about 4-6 days). It was found that 1-2 months after the commencement of prolonged administration an equilibrium occurs between the amount of Co⁶⁰ introduced, the amount retained in the organism and the secreted amount.

The earliest changes were found in the blood system; increased amount of hemoglobin and erythrocytes, leucocytosis and lymphocytosis were found only in the group of animals receiving the smaller doses of cobalt - 1.65 μ C/kg. Starting from the ninth month, in the rabbits receiving 16.5 μ C a gradual fall in the total amount of leucocytes, an account of the lymphocytes, was noted, and by the 21st month the number of lymphocytes dropped by 35%. In particular, deficiency of the blood formation system appeared in parturition and with hemorrhage. Early (in one to two months) the albumin-globulin coefficient fell. In the seventh month the permeability of the eye vessels increased and in the ninth month those of the skin. The electrical activity of the heart was changed. Within 15-20 months the glycogen-formation function of the liver and the activity of certain enzymes in carbohydrate metabolism were disturbed. In the females procreation capacity diminished. In the same period, in some rabbits, tumors of various localizations were found.

Use of the calcium disodium salt of cyclohexane diaminotetraacetic acid promoted excretion of Co⁶⁰ from the organism (up to 67% compared with the controls).

The data of the chronic experiment show that the maximum permissible level (m.p.l.) for Co⁶⁰ in water, proposed by Morgan, was exceeded in not less than two series, which allows one to consider as biologically justified the m.p.l. of 5×10^{-9} in water adopted in the Soviet Union.

Institute of Industrial Health and Occupational Diseases
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LAWFUL NATURE OF BEHAVIOR, RESORPTION, DISTRIBUTION AND
EXCRETION OF RADIOACTIVE ISOTOPES IN THE ORGANISM

I. P. Tregubenko

The speed and degree of resorption of radioactive isotopes from the primary depot (site of entry into the organism) depend not only on the form in which the emitter is administered, but on the form in which it passes into the primary depot, and also on the gravimetric dose administered.

The behavior of the resorbed radioisotope in the organism is identical to the behavior of the unweighable amount of it injected directly into the blood stream.

The speed of removal from the blood, the character of distribution in the organs and also the degree and routes of excretion of the emitter depend on its physicochemical state in the blood.

Often the radioactive substances (metals) may, by the phenomenon of their distribution in the organism, be divided into three groups: "skeletal" ("pure skeletal" and "predominantly skeletal"), "hepatic" and "uniform". The "hepatic type" passes with time into the "skeletal".

The character of distribution of "predominantly skeletal" emitters when administered directly in the blood stream depends on the gravimetric dose, the form and also on the valency of the metal introduced; the "predominantly skeletal" type may be transformed into the "hepatic".

The emitters of the "hepatic" type are excreted from the organism essentially in the feces; excretion of them in the urine is insignificant. The predominant excretion of the "skeletal" emitters in the urine in the first few days is replaced in the later stages chiefly by their excretion in the feces. Almost all the emitters of the "uniform" type are excreted from the organism chiefly in the urine.

The degree and speed of resorption, the character of distribution and magnitude of excretion of the emitters (metals) introduced in the form of complex compounds depend on the stability of these compounds within the organism.

Biological factors (age, sex, diet) in a number of cases quantitatively affecting the metabolism of the metals in the organism (resorption capacity, deposition in the organs and excretion) do not alter the basic pattern of their distribution in the tissues and the character of their excretion from the organism.

Certain complex-formers have significant influence on the fate of the emitters (metals) in the organism.

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EXPERIMENTAL BIOLOGICAL ESTIMATION OF THE MAXIMUM PERMISSIBLE
LEVEL OF RADIOACTIVE ISOTOPES ON ENTRY INTO THE ORGANISM

M. G. Durmishyan

The problem of the maximum permissible doses and levels of the various substances including radioactive isotopes is at once a general biological and special health problem.

In line with the teaching on the laws of reactivity of the living substrate to the effect of environmental stimuli, propounded above all by N. E. Vvedensky and I. P. Pavlov, the character, degree and duration of even initial reactions is conditioned by the qualitative and quantitative characteristics of the stimuli and the functional state and "mobility" of the reacting substrate. Hence it follows that the concept of the "maximum"

permissible dose is relative. The degree of this relativity will be all the greater the greater the number of factors influencing the reaction of the organism.

These factors, in the case of the action of radioactive isotopes on the organism, have much in common with the factors encountered in the standardization of stimuli of a nonradioactive nature. But peculiarities do exist.

One may point to at least eleven factors with a direct bearing on the determination of the maximum permissible levels of radioactive substances.

1. The character and energy of irradiation; 2. the radioactive half life; 3. the period of semi-excretion of the radioactive isotopes from the organism; 4. the routes of infiltration into the organism; 5. the character of their distribution in the organism; 6. the sensitivity and reactivity to radiation of the tissues, organs and systems; 7. the integral sensitivity and reactivity of the organism to radiation; 8. species sensitivity; 9. age and sex sensitivity; 10. latent period of biological "chain" reactions; 11. remote genetic sequelae.

All these factors may be divided into two groups: physical and biological. The physical factors can be determined with comparative ease by the computation method. The biological factors can, however, be subjected to mathematical calculation only with difficulty.

In order to transfer animal experimental data to man, one must make wide and critical use of the information gained by inspection of the conditions of work in places where isotopes are employed, and also of the results of the clinical physiological investigations of the dynamic aspects of the functional changes in persons employed in the corresponding industries.

In the report certain preliminary results of work on the individual questions touched on here will be given, work conducted by co-workers of the Department of Radiobiology (V. P. Godin, V. G. Golubev, S. I. Gorkhov, V. M. Zakharov, L. V. Zhidkova and E. N. Ryumina).

Moscow Erisman Scientific-Research Institute of
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INFLUENCE OF SMALL (TRACER) DOSES OF RADIOACTIVE ISOTOPES ON MORPHOLOGICAL AND BIOLOGICAL BLOOD COMPOSITION

R. E. Kavetsky, L. B. Stolyarova, R. D. Nikitenko and N. M. Amdurskaya

1. Extension of the field of application of radioactive substances in the national economy and in science has had the result that, in the course of day to day work, a large number of people come into contact with small doses of ionizing radiations.

Consequently, study of the irradiation influence on the human organism of small doses of radioactive substances is of ever increasing interest and topicality.

In our laboratory the influence of small (tracer) doses of radioactive isotopes of phosphorus, iron, strontium and cobalt on the morphological and biochemical composition of blood has been investigated.

2. We studied the changes in the peripheral blood picture of a rabbit with intravenous administration of small doses of radioactive isotopes. The blood was examined on the first, second, third, fifth, seventh, tenth and twenty-first day after administration of the isotope.

In the experiments with radioactive phosphorus and cobalt the early blood reactions were determined — at the moment of administration of the isotope, and 3, 5, 10, 15, 30 mins, and 1 and 4 hours after introduction of the

isotopes; in the experiments with radioactive strontium the reactions of the blood to repeated introduction of the isotopes were investigated.

3. Both the tracer doses and large doses of β and γ emitters cause definite early changes in the peripheral blood. The general character of the changes corresponds to changes brought about in the blood by large doses of these same isotopes and also by other sources of external radiation.

In all cases we noted a fall in the total number of leucocytes on counting the lymphocytes in the early stages, i.e., 1 - 4 hours after introduction of the isotope; gradual development of neutrophil leucocytosis 4 hours, and on the first, second, and sometimes third days after injection of the isotope, with subsequent transition to leucopenia followed by more or less stable normalization towards the 10th-12th day of investigation.

Only with administration of radioactive Co was there some modification of the changes, particularly at a dose of $1 \mu\text{Ci}$; these modifications were expressed in a later onset of the changes on the part of the neutrophils, and in quantitative differences.

The changes on the part of the red blood cells with single administration of the isotopes investigated were slight and did not exceed the limits of physiological fluctuations.

4. With repeated administration of radioactive strontium there were marked changes on the part of the red blood cells culminating in a substantial and quite persistent fall in the number of erythrocytes and also deep disturbances on the part of the white blood myeloid series, which were absent upon introduction of a single dose.

5. Large doses of the radioactive isotopes investigated by us induce more marked qualitative and quantitative changes on the part of the peripheral blood.

β -radiation of radioactive phosphorus and radioactive strontium in equiradioactive doses exert a much more damaging influence than γ -radiation of radioactive iron and radioactive cobalt.

6. Change in the biochemical composition of the rabbits' blood under the influence of small (tracer) doses of radioactive isotopes was studied. It was shown that $5 \mu\text{Ci}$ radiophosphorus raises the rabbit blood sugar content by 21-63%, this increase being lowered in proportion to duration of direct starvation.

One may suppose that the tracer doses of radioactive phosphorus induce an increase in blood sugar level in the rabbits on account of mobilization of liver glycogen.

The mechanism of this hyperglycemic reaction is of a neuroreflex character, since a similar hyperglycemia may be obtained with administration of radioactive phosphorus in an isolated arterial vessel and cannot be noted with introduction of radiophosphorus in conditions of starvation of the animals, deep narcotic sleep and removal of the suprarenals.

7. Small (tracer) doses of radioactive isotopes induce definite changes in the morphological and biochemical composition of the blood analogous in character to the changes induced by large doses.

It seems to us that small doses of radioactive substances are of no small significance for the organism especially when the possibility of their prolonged influence is taken into account

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TISSUE DOSIMETRY OF α -ACTIVE SUBSTANCES

A. M. Kononenko

Great attention has been aroused by the question of the distribution of the dose of ionizing radiations in the tissue structures since the character of this distribution fundamentally influences biological effect. Boyd and Fink point that on the basis of the mean dose, polonium is 54 times, and plutonium 29 times more toxic than radium. It is obvious that such a difference is related to the varied distribution of these elements in the organism.

Many tissue structures are separated from each other by a boundary, cylindrical in form. In connection with this, it is of interest to determine the distribution of the magnitude of the dose between two media divided by a cylindrical boundary.

The density of α -radiation energy flow through flat and spherical boundaries between the two media containing the α -emitter was determined. The expressions obtained are of the following form:

$$dE_i = \frac{N_i E_{\alpha} R_i}{8} d\delta$$

$$dE_i = \frac{N_i E_{\alpha} R_i}{8} \left(1 - \frac{1}{24} \frac{R_i^2}{a^2} \right) d\delta$$

$$\infty \gg a \gg \frac{1}{2} R_i$$

where N_i = the number of α -particles, arising in a unit of time per one unit volume of medium i ; E_{α} = energy of α -particle; R_i = range of α -particle in medium i ; $d\delta$ = differential element of border surface; a = radius of sphere. In equation (2) medium $\ll 1 \gg$ is in sphere, medium $\ll 2 \gg$ outside it.

Since the effective curve of a cylinder is less than that of a sphere of the same radius, the value of the density of the energy flow through the cylindrical surface must be an intermediate value between the values (1) and (2).

Taking as the density of the energy flow through the cylindrical surface the mean values of (1) and (2), we obtained the following equation for the mean magnitude of the dose in the cylindrical boundary volume

$$P_{\alpha_1} = E_{\alpha} \left[N_1 - \left(N_2 \frac{R_2}{R_1} - N_1 \right) \frac{a}{4(2a - R_1)} \left(1 - \frac{1}{48} \frac{R_1^2}{a^2} \right) \right]$$

$$P_{\alpha_2} = E_{\alpha} \left[N_1 + \left(N_2 \frac{R_2}{R_1} - N_1 \right) \left(1 - 1.4 \frac{a}{R_1} + 0.65 \frac{a^2}{R_1^2} \right) \right]$$

where a = radius of cylinder, medium $\ll 1 \gg$ within cylinder, medium $\ll 2 \gg$ outside it.

The values of the mean magnitude of the dose calculated according to (3) and (4) are in good agreement with the experimental findings.

Central Roentgen-Radiological Scientific Research
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CHANGE IN HEPATIC CARBOHYDRATE FUNCTIONS IN POLONIUM DAMAGE

V. P. Fedotov

It is known that subjection of the organism to ionizing radiation greatly reduces the glycogen content of the liver. At present there are two differing opinions on the mechanism of this disturbance. Some authors hold that with radiation disease the sugar-fixation and glycogen-formation functions of the liver are disturbed; others are inclined to regard glycogen impoverishment of the liver as a result of disturbances in feeding and in the activity of the gastrointestinal tract.

In dogs subjected to angiotomy we succeeded in showing that with acute and subacute course of radiation disease, induced by polonium, there is distinct disturbance in the sugar fixing function of the liver. This disturbance was observed both with orally administered glucose and with intravenous injection of glucose.

The experiments with intravenous injection of insulin showed that in conditions of acute and subacute radiation disease the liver continues to react to insulin, but the character of the hypoglycemic curve changes. Primary hyperglycemia occurring with intravenous injection of insulin increases both in magnitude and time.

The times of maximum hypoglycemia and return of blood sugar to the original level shift to later stages. The degree of hypoglycemia was practically unchanged.

Experiments with intravenous injection of adrenalin established that with disease of the organism by polonium the liver responds to injection of adrenalin by a more intense output of sugar into the blood. The return of blood sugar content to the original level occurred somewhat later than normal.

The results of our investigations enable one to conclude that with disease of the organism by lethal doses of ionizing radiation the sugar fixing function of the liver is lowered. This finds expression in impaired capacity of the liver to take up sugar from the incoming blood and to fix sugar firmly.

USSR Academy of Medical Sciences

INFLUENCE OF β -RADIATION (P^{32}) ON GLYCOGEN FUNCTION OF THE LIVER

G. Kh. Bunyatyan and G. T. Alunts

The influence of β -radiation of P^{32} on the glycogen function of the liver was studied. The experiments were conducted on 18 rabbits distributed in equal numbers in the control and experimental groups. Determination of glycogen was made according to the method of Gudkremmer and Somodzh. It was found that normally glycogen is unequally distributed in a hepatic lobe. Most of it was found in the terminal parts of the lobe (4.38 g %) and less in the central part (3.69 g %).

Radioactive phosphorus in the form of $NaHP^{32}O_4$ solution was injected subcutaneously at the rate of 20-30 μ C per 1 kg body weight. The animals were killed 24 hours after introduction of the isotope. The investigations showed that after introduction of the P^{32} solution in the dose indicated, the amount of glycogen in the liver fell 5-10 times (in particular cases 15-20 times) as compared with the control rabbits, reaching 0.1 %. These changes were observed in all parts of the hepatic lobes. It should be noted that under the influence of P^{32} the difference in the glycogen content in the various parts of the liver disappears. The same amount of stable phosphorus introduced subcutaneously did not have any effect on the glycogenic function of the liver.

With subcutaneous administration of insulin on the basis of 3 units per 1 kg rabbit body weight and Na_2HPO_4 solution, the glycogen content of the liver fell much less (3-7 times) than under the influence of radioactive phosphorus alone.

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DESTRUCTION OF THYROID GLAND BY INTERNAL IONIZING RADIATION (RADIOACTIVE IODINE) AND CERTAIN MEANS OF DEFENSE

Ya. M. Kabak and M. M. Nikitina

This communication continues investigations reported earlier.

NaI^{131} , without a carrier, was introduced at various doses in single administration under the skin of one-day-old rats. In each litter there were six rats. Altogether over 60 litters, i.e., about 360 animals, not counting the mothers, were used.

The minimum dose inducing, in the conditions of these experiments, practically complete destruction of the thyroid gland, was roughly equal to $100 \mu\text{Ci}^{131}$, which corresponds to the findings of Goldberg and Chaikov.

Physiological sequelae of such destruction were observed: retardation of growth and bone formation process, disturbance in development of hairy integument, changes in general appearance, behavior and state of animals, disturbance in heat regulation, etc.

All these disturbances are considered as results of destruction of the thyroid gland since even after becoming clearly apparent, it was possible to remove them by substitution therapy with thyroïdin (5 mg/100 g animal weight daily).

At the conclusion of the experiments, the completeness of destruction of the thyroid gland was controlled by histological examination of the relevant regions of the trachea by the method of serial sections.

Additional proof of the athyroid state of the animals was obtained by examination of the cytological structure of the frontal lobe of the pituitary; in the rats subjected to radiothyroidectomy it changed in a characteristic fashion, and in animals receiving thyroid its normal state was restored.

Of particular interest are the results of the experiments with "defense" of the thyroid gland against destruction by radioactive iodine entering the organism.

As in the previous investigation on birds, a favorable effect of stable iodine salts (iodide) was observed, but a particularly good effect was achieved with use of 2-mercaptoimidazole.

In all rats which received adequate dose of this preparation (for example, 4 doses of 0.1 mg for two days) commencing 1-3 hours after entry of I^{131} into the organism, the thyroid gland was well preserved and no defects or any changes in its function were later observed.

Only on histological examination of the thyroid gland was it possible to detect certain consequences of its partial destruction.

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INFLUENCE OF COMPLEXONES ON MINERAL EXCHANGE IN THE ORGANISM

D. I. Semenov

Laboratory investigations (1949-1956) on the influence of a series of complexones on the behavior of radioactive elements (metals) in the organism showed their high efficacy. Ethylene diaminetetraacetate (EDTA), hexametaphosphate (HMP), poly- and metaphosphates, nitro triacetate (NTA), cyclohexane (CH) and uranyl diacetate (UDA) exert a significant influence on the deposition of a number of metals in the organs and tissues and also on the speed of their excretion from the organism.

EDTA to a considerable degree accelerates the excretion of a number of emitters (metals) from the organs and tissues at late stages of poisoning.

The mechanism of excretion of emitters (metals) from the organism by the complexones consists in formation of highly stable complex compounds highly soluble in the conditions of the organism, easily and speedily filtering through the kidneys.

The mechanism of the toxic action of the complexones of the EDTA type consists in binding of biologically important cations.

The efficacy of the complexone in the excretion of the various emitters (metals) depends on the constant of displacement of calcium, the stability of the complex in the biological medium, the physicochemical state of the metal in the blood and tissues, and also on the speed of the process of complex formation.

The efficacy of the complex compounds in the excretion of the emitters (metals) depends on the constant of the displacement of the metal of the introduced complex by the emitter (metal).

The toxicity of the complex compounds depends on their hardness in the conditions of the organism.

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COMPARATIVE EVALUATION OF AGENTS SPEEDING UP EXCRETION OF RADIOACTIVE STRONTIUM

E. I. Safronov

Comparative evaluation of agents accelerating excretion of radiostrontium from the organism was made by radiochemical and biological methods. In the preliminary series of radiochemical experiments with static and dynamic ion exchange chromatography, the capacity of organic and inorganic chemical compounds to remove radiostrontium from cationic resins was compared. Of the 20 tested compounds the most effective in the radiochemical experiments were lithium citrate, potassium iodide, iodihypersol and trilon B.

The results of the radiochemical experiments were used in biological experiments, and confirmed and verified in particular cases by radioautographic examination. Chronic series of biological experiments were performed on 630 mice. In these experiments, excretion of radiostrontium from the organism was appreciably accelerated by repeated subcutaneous injections of 0.2 ml daily of 5% lithium citrate solution for the first five days of poisoning.

Physiological saline accelerated excretion of radiostrontium from the mouse organism to a much smaller degree; however, it did have a definite medicinal effect, reducing mortality in the mice and the intensity of the clinical picture of poisoning by radiostrontium. Potassium iodide did not possess any medicinal advantages over physiological saline.

Analysis of the multistage investigations conducted and the published findings enable us to conclude that physiological saline and potassium iodide along with salts of citric acid and other substances may be recommended in the treatment of radiostrontium poisoning.

Kirov Order of Lenin Military-Medical Academy

INFLUENCE OF UNITHIOL ON DISTRIBUTION, ACCUMULATION AND EXCRETION OF RADIOACTIVE ARSENIC IN RABBITS

N. I. Lugansky and Yu. I. Loboda

Dithiol, containing in its molecule active sulphydryl groups is now being successfully employed as a means of antidote therapy in poisoning by arsenic compounds and certain heavy metals ("thiol poisons").

Of the compounds of this type especially noteworthy is a new national preparation unithiol (2, 3-sodium dimercaptopropansulfonate) put forward by the Ukrainian Chemical Hygiene Scientific-Research Institute (V.E. Petrunkin, V. P. Dverntsiy, A.I. Cherkas and co-workers).

The work performed in our laboratory in the last few years (N. I. Lugansky, D. S. Lukontsev) has shown that unithiol is a highly active antidote in poisoning of animals by various organic and inorganic arsenic compounds (novarsenol, osarsol, calcium arsenite, Paris green, arsenic anhydride, etc.)

In the mechanism of the therapeutic action of unithiol in arsenic intoxication, its capacity to increase excretion of arsenic from the organism is of definite importance.

To make a more thorough study of the therapeutic properties of unithiol and its role in the detoxication processes in the organism we set out to investigate the influence of the preparation on the distribution and accumulation of arsenic in the organs and tissues, and also to trace the speed of excretion of the poison from the animal organism poisoned by arsenic anhydride.

In performing these experiments, the method of radioactive tracers was applied. The isotope of arsenic in the form of arsenic anhydride ($As_2^{76}O_3$) was employed. The experiments were carried out on 75 rabbits.

The findings of our experimental investigations suggest the following conclusions:

1. Unithiol greatly reduces the content of radioactive arsenic in the organs and tissues of rabbits within the course of only a few hours after introduction of the isotope.
2. With treatment by unithiol, elimination of the radioactive arsenic in the urine considerably increases, particularly in the first few days.
3. The material obtained for study of distribution, accumulation and excretion of radioactive arsenic in animals treated with unithiol confirmed our former data demonstrating that in the mechanism of the medicinal antidote properties of unithiol an important part is played by its capacity to intensify elimination of arsenic from the organism.

Ukrainian Scientific Research Chemical-Hygiene Institute

IV. BIOCHEMISTRY AND PHYSIOLOGY

LABELED ATOMS AND STUDY OF PHOTOSYNTHESIS AS A PHYSIOLOGICAL PROCESS

A. A. Nichiporevich

The labeled atom method is being widely employed in the study of the course of photosynthetic transformations of carbon, and especially of the primary and direct products of photosynthesis.

In this direction important material has been obtained which has shown the cyclical character of the process and has demonstrated a number of initial and intermediate products.

However, these were purely biochemical investigations.

Up to now, many questions in this field have remained unclear and controversial (the question of the nature of the primary acceptor or acceptors and the question of the primary product or products, etc.). In this respect much work needs to be done.

Several problems of the chemistry of photosynthesis have unfortunately not been treated to any extent. Among these is, for example, the important question of the way in which oxygen is evolved in the photosynthetic process. An aspect of the question of no less importance, and in some respects of more importance, is the application of the labeled atom method to the study of photosynthesis as a physiological process, above all from the point of view of the possibility of increasing the productivity of photosynthesis.

In this connection, much important work has been started or partially completed. Thus, work has begun which has given results on the study of the relations between photosynthesis and respiration.

Work has started on the study of the significance of the atomic-cytological structure in photosynthesis.

The labeled-atom method is of great assistance in the study of the question of the mechanism of energy accumulation and transfer in the photosynthetic process, in particular as a result of formation of macroergic phosphate bonds.

Our conceptions on the diversity of products of synthesis and also on the methods and causes of their formation have now been considerably extended.

Work has started on the connections between the special nature of the work of the plant photosynthetic apparatus and a series of physiological processes (nutrition, growth, light conditions, photoperiodic reactions, etc.).

Much of this work is now in an embryonic state. However, because of the significance of this question and of the results which may be achieved, this work needs to be extended in every direction.

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POLYGLYCERIC ACID IN THE PRIMARY PRODUCT OF PHOTOSYNTHESIS

E. A. Blochenko and N. I. Zakharova

In studying the products of reduction of $C^{14}O_2$ in photosynthesis radioactivity was detected first of all in an oxyacid with a molecular weight of about 1,500. Determinations of the constituent elements and functional groups of this oxyacid showed that the entire carbon was to be found in carboxylic and alcoholic groupings. On decomposition, glycerol derivatives were obtained. In view of the fact that several authors have described phosphoglyceric acid as the primary product, it was interesting for comparison purpose to determine glycerol and phosphorus not hydrolyzed by 1 N HCl in the primary product molecule, to which we gave the designation R^1 . Glycerol was determined by the periodate method showing that it constituted about 6% by weight of the product. The remaining carbon in the molecule was to be found in the carboxylic groups. Total phosphorus, differentiated inorganic and organic phosphorus, was determined by the method of Fiske-Subbarow. All the phosphorus in R^1 was in organic combination. Then it was determined whether the phosphorus was resistant to three-hour hydrolysis with 1 N HCl. Comparison of the amounts of nonhydrolyzable phosphorus and glycerol showed that had this product consisted of phosphoglyceric acid the amount of phosphorus should have been many times greater. Upon heating with naphthoresorcinol in concentrated sulfuric acid a blue color was obtained characteristic of glyceric acids. Thus, the primary product of photosynthesis was a polyglyceric acid.

Paper chromatography confirmed the homogeneous nature of the substance, both in two-dimensional and wedge chromatograms. Upon boiling with ethyl alcohol for one hour, decomposition took place yielding glycerol derivatives with different R_f values, and the residual molecule contained iron.

The path of the carbon in photosynthesis starts out in combination between carbon dioxide and the iron containing fraction of the R^1 molecule. Already reduction occurs, since in the primary product no more than 50% of the C^{14} is found in the carboxylic groups. The alcohol groups, formed on deoxidation, forming part of the glycerol fraction of the molecule, are then split off from R^1 . This differs from Calvin's hypothesis, apart from the nature of the carbon dioxide acceptor, in that he considered the primary product not a result of local reduction but a subsequent stage of phosphotriosis. However, the data on the distribution of C^{14} in individual atoms of the molecule, both of the glyceric acids and the hexoses, contradicts the hypothesis that the monoses originate in the trioses. Discovery of radioactivity in dioxycetone may be explained by the formation of this substance upon decomposition of R^1 . The subsequent transformation of carbon into free sugars occurs through the product R^{11} , two thirds of which is composed of uronic type acids and one third of ketose. The transfer of the ketose formed here to the various organic acceptors may, according to the latest work on the transference effect of invertase, lead to formation of many substances including free sugars.

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STUDY OF THE PROCESS OF RENEWAL OF CHLOROPHYL COMPONENTS WITH THE AID OF LABELED CARBON

A. A. Shlyk and T. N. Godnev

From the observations reported in the literature, one can deduce almost anything from the correlations logically possible between the biosynthesis of chlorophyll-a and chlorophyll-b. Since we have shown that complete synthesis of the molecules of the pigment occurs even with its renewal, study of this process has also led to new conclusions on this question. For example, we established in three plants a difference in the

specific activities of carbon in chlorophyll-a and -b, indicating a different speed of incorporation of carbon and assimilable CO_2 . It is probable that such a difference is due to the nonuniform attenuation of the new molecules in the tissue by the amount of pigments. This difference was maintained for a fairly long period of time, suggesting that in the plant rapid mutual transformation of the two chlorophyll components does not occur. The significance of chlorophyll-b in photosynthesis cannot be associated with such a mutual transition as has occasionally been claimed. Splitting of the chlorophyll molecules and determination of the radioactivity of its parts showed that components a and b are capable also only of slow phytochemical change. Chlorophyll-b, possessing a smaller specific activity, cannot be a precursor of chlorophyll-a. The basically uniform distribution of radioactivity throughout the molecules of chlorophyll-a and -b precludes the possibility of independent biosyntheses of the two components of chlorophyll and shows that they are formed from common precursors. The single chain of biosynthesis either continues up to formation of chlorophyll-a and, from it, chlorophyll-b or branches out at one of the final stages leading to a parallel emergence of both chlorophyll components. The choice of the most likely of these two possibilities was made on the basis of an experiment in which restoration of the chlorophyll occurred simultaneously with continued storage of the pigment and the relative specific activity of chlorophyll-a and -b was calculated according to the activity of the simultaneously isolated succinic acid, the chief source of carbon of the phorbins. The value obtained for chlorophyll-b throughout the experiment was less than the increase in the amount of pigment. This shows that on the path from succinic acid to chlorophyll-b a considerable decrease in the specific activity of carbon occurs, much greater than occurs on the path to chlorophyll-a. Such an attenuation is difficult to explain on the bases of the hypothesis of parallel emergence of both pigments. If chlorophyll-a arises successively from chlorophyll-b, this attenuation is not only explicable but essential. The transition through chlorophyll-a is, in such a case the main stage at which attenuation of the carbon of chlorophyll-b takes place. Final solution of this complicated question requires further investigations.

Institute of Biology of the USSR Academy of Sciences

INVESTIGATION OF INTERMEDIARY PRODUCTS OF PHOTOSYNTHESIS BY MEANS OF RADIOACTIVE ISOTOPES

N. G. Doman

With the isotopic method and use of poisoning of enzymatic systems, new data have been obtained confirming the presence of a stage of unstable foliar binding of CO_2 prior to the stage of formation of phosphoglyceric acid, the first stable product in photosynthesis.

The phosphoglyceric acid formed may be converted simultaneously in several directions, but it is essentially reduced to trioses by incorporation in the carbohydrate photosynthetic cycle, in the course of which a certain amount of phosphoglyceric acid quickly reappears, no longer labeled by the carboxylic carbon, but by the carbon in the α and β positions.

Study of the course of formation of the early intermediate products of photosynthesis in various plant species in changing conditions demonstrates that although there is uniformity in the basic stages of the path of the carbon in photosynthesis, even at the very commencement the nature of metabolism is specific to the plant and dependent on conditions.

Data were obtained showing a certain connection between CO_2 assimilation in light and darkness in the synthesis process of plant substances.

The detected intensification of reduction of sulfates in the leaves in the light may be due to direct participation of organic sulfur compounds in the photosynthetic process.

A. N. Bakh Institute of Biochemistry of the USSR Academy of Sciences

USE OF RADIOACTIVE CARBON (C^{14}) IN THE STUDY OF
THE INFLUENCE OF TRACE ELEMENTS ON PHOTOSYNTHESIS AND
TRANSLOCATION OF ASSIMILATES

M. Ya. Shkolnik and A. N. Greshishcheva

The question of the influence of trace elements on photosynthesis and translocation of assimilates is of great interest. Data on this question are few in number and often contradictory. The most definite data are those in relation to the significance of manganese and iron in the process of photosynthesis and on the positive influence of boron in carbohydrate translocation.

The object of our work was to study the influence of boron, manganese, copper, zinc and molybdenum on the intensity of photosynthesis and on the translocation of the assimilates at various times of the day.

The experiments were performed in cotton plots.

In all the experiments, photosynthesis and translocation of assimilates was studied by means of the radioactive isotope of carbon (C^{14}).

As a result of the investigations carried out the following conclusions may be drawn:

In experiments conducted on the cotton plant, copper and manganese had an appreciable positive influence on the intensity of photosynthesis and displayed the capacity of reducing or completely removing depression of photosynthesis during daylight hours.

Zinc and molybdenum, in the majority of cases, had a positive influence on photosynthesis, chiefly in daylight hours, which indicates that they are also capable of reducing depression of photosynthesis. The use of boron gave contradictory results.

The question of the influence of zinc, molybdenum and boron on photosynthesis requires further checking.

Boron and manganese accelerated the translocation of the labeled assimilates from the leaves in almost all cases. Zinc and molybdenum, in most cases, had a positive influence on this process. Contradictory results were obtained for copper.

Accelerated translocation of the C^{14} -labeled assimilates was detected under the influence of boron in experiments with sugar beet (introduction of boron in the presence of high doses of lime which hampers translocation of assimilates). These data explain one of the reasons for the particular significance of boron in presence of high doses of lime. In these experiments it was established that the optimal dose of lime, unlike a high dose, improves the assimilate translocation.

Our findings are in agreement with the findings in the literature on the positive influence of manganese on photosynthesis and of boron on the translocation of assimilates, and shed light on the influence of copper in photosynthesis.

They show furthermore, the great significance of manganese in translocation of assimilates.

V. L. Komarov Botanical
Institute of the USSR
Academy of Sciences

TRANSLOCATION OF PRODUCTS OF PHOTOSYNTHESIS
IN SOYA PLANTS AND QUESTIONS CONNECTED
WITH HARVEST YIELD

I. F. Belikov

Study of the movement and distribution of products of photosynthesis in the soya plant in the vegetative period was necessary to produce a scientific basis for the use of standard seed screening and methods of sowing in soils of different fertility. In the investigations radioactive carbon (C^{14}) was employed.

Before bean formation, the assimilates from the old leaves of the plant are usually directed towards the growth points of the runners, to the young expanding leaves, stem and root. They were found in the largest quantity in the tissues and organs in which active processes of growth and metabolism were occurring at that period. Radioactive carbon was not found in the leaves and other parts of the plants in which growth was complete when the nutrient was administered.

When the beans appeared, the flow of plastic substances to the growth points and the young growing leaves ceases. The products of photosynthesis are used locally, i. e., from each leaf they enter the axial bean.

The assimilates move from the leaf to the stem, moving upwards and downwards simultaneously, usually five to six times more passing downwards than upwards.

In normal conditions of growth and development the bean's requirement of plastic substances is higher than can be produced by the assimilation apparatus of the plant.

When a bean falls off, the substance accumulated in the leaf is taken over by beans at neighboring nodes.

With the appearance of beans on the plant, a smaller amount of the products of photosynthesis enters the root system. It must be assumed that the vital activity of the root system is maintained on account of stored substances.

Establishment of the characteristic of distribution of the products of photosynthesis in the plant organism in the period of vegetation and the soya plant's need of secondary light, established by us earlier, enabled us to explain the cause of the low soya yield in continuous sowings and to lay down rational standards of seed screening and methods of sowing in soils of different fertility.

Far Eastern Branch of the
USSR Academy of Sciences

USE OF N^{15} IN STUDY OF THE ROLE OF NITROGEN
NUTRITION IN THE HARVEST YIELD

V. V. Tserling

The object of the investigation was to make clear the times of administration and doses of nitrogen in nitrogen metabolism, and the role of nitrogen in the formation of the reproductive organs.

In order to distinguish the effect of nitrogen introduced before sowing from the nitrogen introduced after, the technique of marked atoms was used.

It was found that nitrogen metabolism in plants depends on the original dose of nitrogen and the times and phases of development of the plant.

The influence of the different levels of nitrogen intake before sowing on nitrogen metabolism in the first period of development of the plant, and as a result of this, on the subsequent stages of formation of the reproductive organs was shown.

Isotopic analysis made it possible to distinguish more clearly the entry and transformation of the nutrient nitrogen than did quantitative determination of the percentage nitrogen content in the fractions.

It was established by the isotopic method that:

- 1) synthesis and restoration of amino acids precedes synthesis of albumin;
- 2) in the first hours and days after intake of nutrient this process proceeds with particular vigor;
- 3) the greater the hunger of the plant before nutrient administration, the more rapid the new formation of amino acids at the expense of the nutrient nitrogen;
- 4) renewal of albumin nitrogen at the expense of labeled amino acids is more vigorous in young (20 day) plants.

Use of $N^{15}H_4N^{14}CO_2$ as a labeled fertilizer made it possible to confirm experimentally the thesis of Acad. D. N. Pryanishnikov, that ammonia is taken up more quickly than are nitrates.

Changed nitrogen nutrition in plants most strongly affected the development process of the reproductive organs and grain harvest formation.

Spacing of the dose of nitrogen in all cases produced an increase in the harvest, differing according to the variants of the experiments. One and the same dose, but introduced at a more advantageous time, by activating nitrogen metabolism in the young plant, accelerated the formation of panicles, increased the ripening of the inflorescence and the grain harvest.

A characteristic of plants with the largest panicles and grain yield was the similarity of the indices of amino acids and albumin synthesis in the phase before and during differentiation of the panicles.

By varying dosage and times of administration of nitrogen fertilizer, and thus intensifying nitrogen metabolism in the plants at a definite phase of their development, one can produce any size and kernel type of panicles of millet, and consequently, change the grain harvest.

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NEW METHOD OF DIFFERENTIAL STUDY OF LOCALIZATION OF RADIOACTIVE SUBSTANCES IN PLANTS BY MEANS OF AUTORADIOGRAPHY WITH USE OF FILTER PAPER LEAF "IMPRINTS"

Zh. A. Medvedev

Normal autoradiography of plant objects, although plainly showing the localization of radioactive substances, does not, however, clearly reveal to what extent the radioactive substances are concentrated in the various compounds (albumins, nucleic acids, lipoids, inorganic substances), since the film is a summation of all the radioactive fractions in the plant tissues. This peculiarity of autoradiography of large objects restricts its use in biochemical and physiological investigations connected with analysis of substance transformation by the study of synthesis of various complex compounds.

The author devised a method of differentiated leaf autoradiography of particular labeled compounds (albumins, nucleic acids, lipoids), and also of separate fractions of cells (vacuole and plasma, solutions cellular structures). The basis of this method is the securing by means of high periodic pressure (150-200 atmos.) of "impressions" of leaves on filter paper. In obtaining the "impressions", the foliar intracellular contents are pressed in the filter paper with retention of the typical leaf impression, which makes it possible to eliminate from such an imprint, by washing, one or another soluble fraction using solutions which fix the albumin and nucleic acid fractions on the filter paper (for example, washing of "imprints" by a solution of trichloroacetic acid), with subsequent autoradiography of the "imprints". Conditions have been worked out in which only the vacuole or plasma liquor of the leaf is sucked into the filter paper by gradual increase in pressure on the leaves denatured by freezing and also conditions enabling one to obtain an "imprint" of the plastids and organoids of leaves after preliminary removal of the liquid fractions (using leaf "imprints" on paper impregnated with trichloroacetic acid). With use of preliminary trichloroacetic acid impregnation of the paper all the albumins removed from the leaves under pressure are fixed in the surface layer of the paper, which heightens the distinctness of the "imprint" and reduces the radiation self-absorption effect. Preliminary impregnation of the paper by barium or iron salts enables one to fix the labeled inorganic compounds of sulfur and phosphorus in the "imprints." Use of varieties of fine and coarse filter papers enables one to obtain layer "imprints," the content of the leaves being distributed in 5-10 layers of paper, each layer differing from the other in the morphobiological sense, since the organoids of different dimensions (nucleus, plastids, granules, intergranular medium) are retained to a different degree by the individual layers of paper. The method devised is suitable for mass analysis and does not require complicated equipment. In order to obtain the "imprints", various types of chromatographic paper were tested.

The report presents the results of a study with use of the method of autoradiographic "imprints" on localization of albumin and nucleic acid synthesis in the leaves of various strata of kidney beans with root and non-root uptake of S^{35} -labeled sulfates, methionine and with radioactive phosphorus.

Moscow K. A. Timiryazev
Academy of Agriculture

INTENSITY OF ABSORPTION OF PHOSPHORUS AND ITS TRANSFORMATION INTO VARIOUS ORGANIC FORMS IN NONROOT PLANT NUTRITION

V. F. Shcheglova and L. D. Rachkov

In investigations on the question of introduction of phosphorus into plants other than through the root, we set ourselves these tasks: establishing the comparative degree of enrichment of various cotton plant organs by phosphorus-containing compounds with administration of phosphorus via the root and elsewhere; determining the character of the transformation of the phosphorus entering, and the specific composition of organic phosphorus compounds in various organs; and establishing the periods of most active intake in relation to the times of nonroot nutrition.

The advantages of non-root intake of phosphorus are speed of entry, distribution to all organs of the plant, and participation in synthesis of organic phosphorus compounds.

All these processes are slowed down when phosphorus is fed via the root, a certain equilibrium being achieved only in two to three dekada.

Subsequently, root feeding ensures a large flow of mineral phosphorus and more active synthesis of organic phosphorus compounds in the plant.

In view of the fact that soil phosphorus enters the plant more slowly than in nonroot nutrition, additional administration of phosphates through the leaf makes it possible to quickly meet the phosphorus requirements of the plant in the necessary period. Combination of basic root and supplementary nonroot phosphorus nutrition, by most completely satisfying the phosphorus requirements at the opportune moment, can ensure increased plant productivity.

Inorganic phosphorus introduced through the leaf is used by the plant for synthesis of organic and inorganic phosphorus compounds.

The data of radiometric analysis show that the fractional composition of phosphorus-containing compounds is specific for the individual organs of the cotton plant.

A considerable predominance of inorganic phosphorus fraction in the roots, phosphoric ethers of sugars in the fibers formed, and constant growth of nucleoproteins in the ripening seeds was observed.

Phosphorus applied to the leaf enters the plant with greatest intensity at earlier phases of development; at commencement of ripening of the cotton plant entry is insignificant. This explains the very weak effect of non-root phosphorus nutrients in late autumn.

Botanical Institute,
Tadjik USSR Academy of
Sciences

USE OF N^{15} IN THE STUDY OF THE ROLE OF COPPER IN PLANT ASSIMILATION OF NITROGEN FROM NITRATES AND AMMONIA

L. K. Ostrovskaya, B. A. Geller
and G. M. Yakovenko

Copper deficiency in plants is usually manifest in normal or intensified nitrogen nutrition; with insufficiency of nitrogen, copper deficiency has almost no effect on growth and development. According to several findings in the literature, an analogous interrelation is observed between nitrogen and iron. This gives grounds for assuming that heavy metals participate in plant biochemical transformations of nitrogen.

Comparative biochemical investigations of the composition of plants cultivated in conditions of normal and deficient copper nutrition show that when copper is deficient, as a rule, the content of total, albumin and nonalbumin, nitrogen increases. This phenomenon may be a natural outcome of the slowing down of growth of the plants, and does not give sufficient material on which to judge the character of the interrelation of copper and nitrogen metabolism.

Use of the stable isotope of nitrogen has produced data which may be used to approach the solution of the question of the role of copper in nitrogen transformation and albumin synthesis in plants.

Feeding oats with ammonium sulfate containing a stable isotope of nitrogen, and subsequent mass spectrometric analysis of the isolated nitrogen compounds show that in plants not receiving a sufficient amount of copper a somewhat higher percentage of nitrogen atoms are to be found in soluble fractions (NH_4 , amides and amino acids). The N^{15} content of albumins and related compounds is, on the other hand, considerably lowered in copper deficiency.

Analogous but quantitatively weaker correlations were found for sugar beet.

Comparative analysis of sugar beet plants fed by labeled nitrogen in the ammonium and nitrate radicals shows that copper deficiency has no effect on albumin synthesis in nitrate feeding. This fact testifies to the presence of different paths of nitrogen assimilation from ammonia and nitrates. With nutrition by the nitrogen of ammonia, copper deficiency affects albumin synthesis to a larger degree in daylight hours than at night, and reduces the excess percentage of albumin N^{15} atoms not only in the leaves, but also in the roots.

Comparative study of the distribution of N^{15} in various compounds isolated from sugar beet leaves after feeding with nitrogen-labeled ammonium and nitrate radicals indicates that the intake and consequent transformation of the nitrogen in the nitrate radical is much more intensive than that in the ammonium radical especially in nitrogen assimilation in the light. In the roots of the sugar beet, no essential differences in assimilation of the nitrogen from the nitrate and ammonium radicals were observed.

Ukraine Plant Physiology
Scientific-Research Institute

USE OF RADIOCARBON IN INVESTIGATION OF BIOSYNTHESIS OF TERPENES

G. V. Sukhov

In order to determine the speed of biosynthesis of monoterpenes and resin acids, use of the kinetic isotope method of metabolism investigation was employed.

Introduction of radiocarbon (C^{14}) in the experimental plants was conducted in the process of photosynthesis, for which purpose the crowns of 30 year, 10 meter high pines were confined in polyamide-coated sectional photosynthetic chambers, of 60 cubic meter capacity.

The total activity of assimilated $C^{14}O_2$ in each experiment was $10 \mu c$. The chambers were fitted with ventilators for the purpose of forming air currents, thermometers, psychrometers, and counters for constant measurement of the concentration of $C^{14}O_2$.

It was shown that in conditions of light saturation and intensive agitation of air the speed of assimilation of $C^{14}O_2$ is strictly proportional to its available concentration. This technique allows one to study in detail photosynthesis and respiration of ligneous plants in natural vegetation conditions and, with a small refinement of the chamber, rate of transpiration can also be measured.

Following introduction of C^{14} in the experimental trees samples were taken, in the course of 1-2 months, of coniferous needles, bast and wood cellulose from which monoterpenes, resin acids and monosaccharides were isolated. Curves of the radioactivity of the isolated substances were plotted against time. Analysis of the curves showed that the mean duration of life of the monoterpene and resin acid molecules isolated from the coniferous needle of the current year, and the bast and wood cellulose of the branches of the same plant was uniform, being about four days.

One quarter of the effective amount of pine soft resin is renewed in one day. It was shown that the speed of renewal of soft resin exceeds the speed of its secretion on tapping 100 times. In one day, half the pine monosaccharides are restored (mean molecular life span two days). The rate of metabolism of substances formed in the biosynthesis of terpenes from carbohydrates is much greater than the speed of metabolism of both terpenes and monosaccharides. The data obtained give theoretical support to the new technology of intensive tapping and demonstrate the superiority of the kinetic isotopic method of investigation of biosynthesis and metabolism over use of labeled atoms with single measurement of the radioactivity of the investigated substances, a method variant widely employed.

With a single determination of isotopic composition (radioactivity) of the substances during the investigation of their biosynthesis, dissimilar conclusions on the composition of their precursors result because of the multiplicity and reversibility of the paths of biosynthesis and metabolism. The kinetic isotopic method makes it possible to avoid this lack of certainty, and to establish the basic main pathways of biosynthesis, and to measure the speed of transformation of the substances participating in metabolism.

Central Scientific Research
Institute of Wood-Pulp Chemical
Industry

PARTICIPATION OF PENTOSE AND α -METHYL- D-GLUCOSIDE IN LIGNIN FORMATION

Z. N. Kreitsberg and V. N. Sergeeva

Study of the biosynthesis of lignin by means of labeled atoms is a method which holds out much promise for the future. Wide use is now being made of this in research practice.

In this work, use was made of carbon dioxide with a marked carbon atom and α -methyl-d-glucoside synthesized by the authors, as well as pentoses isolated from wood cellulose after intake of carbon dioxide with a labeled carbon atom.

Following foliar feeding of the plants with radioactive carbon dioxide, and also introduction into the plant of the supposed precursors of lignin, pentoses and α -methyl-d-glucoside marked with radioactive carbon we traced the active carbon introduced in the various parts of the plant and also in the lignin of the trunk wood cellulose.

The purpose of the present work was to attempt to define the role of pentoses and α -methyl-d-glucoside in lignin formation.

The experiments showed that with introduction of radioactive pentoses in the plant (young poplar) all parts of the plant became radioactive, as was the lignin isolated from the upper stem.

With injection of radioactive solution of α -methyl-d-glucoside in the plant, radioactivity was not found in the isolated lignin. The wood cellulose contained an insignificant amount of C^{14} .

Upon absorption of radioactive carbon dioxide by the plant through its leaves we established the presence of C^{14} in the separate fragments of the lignin molecule, namely in the aromatic and metaxylene groups in the short side chain.

On the basis of the experiments conducted it was established that:

- 1) pentoses participate in the process of formation of lignin;
- 2) the metaxylene group of α -methyl-d-glucoside is not involved in lignin formation;
- 3) the lignin molecules are formed in one stage, with a definite number of metaxylene groups.

Scientific Research Institute on
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Latvian SSR Academy of Sciences

ISOTOPIC EFFECTS IN BIOLOGICAL PROCESSES

P. A. Vlasyuk and D. M. Grodzinsky

Study of the characteristics of chemical elements isolated from living matter is of particular interest since it is possible that it is precisely in the living protoplasm that conditions are created in which a considerable degree of isotopic differentiation may occur. In addition, the possibility that certain isotopes of elements are of special physiological importance in plant feeding is not to be excluded. Study of this question is of great importance, on the one hand, from the standpoint of geochemistry since the greater part of the elements of the earth's crust is included in living matter and, on the other, for elucidation of the magnitude of isotopic effects in biological processes which is necessary for a proper assessment of results of investigations conducted with the method of labeled atoms.

Acad. V. I. Vernadsky was the first to advance a hypothesis on the possibility of significant differentiation of isotopes in biological processes. At present there is a great deal of information on investigation of isotopic effects dealing with carbon, potassium, hydrogen, calcium, sulfur and nitrogen. Investigations were carried out with elements, both with normal and abnormal isotopic composition. Depending on the experimental conditions, such data show the presence of considerable isotopic effects in a number of cases, although there is much evidence to support relative constancy of isotopic composition of the elements in plants and in nutritive mineral media.

The investigations performed to date are far from sufficient to provide precise knowledge on the isotopic effects occurring in the metabolism of living organisms. Nevertheless, on the basis of existing information on the characteristics of the isotopic composition of elements isolated from living matter, it may be assumed that, in relation to normal isotopic composition, considerable isotopic effects are not witnessed, while with abnormal isotopic mixtures, there may be a significant fractionation of the isotopes in the process of entry and distribution of the element in the plant tissues. Apparently, plants in the process of evolution have adjusted themselves to the normal isotopic composition of the chemical elements. In this connection, in relation to abnormal isotopic compositions in the biological processes, isotopic effects are seen, which give rise to certain changes in the isotopic composition of the elements in plant tissues. Since, with use of the method of marked atoms, abnormal mixtures of isotopes are employed, the possibility of isotopic effects may give rise to certain difficulties in assessment of experimental results.

Where determination of activity is made under stringently uniform conditions of measurement, comparison of the relative activities of various samples may be used to characterize the isotopic effects. Therefore, study of the isotopic effects can conveniently be carried out by using radioactive isotopes. The authors investigated the features of utilization by the plant organism of nutrient elements with abnormal isotopic composition. The abnormal isotopic mixture was produced by addition of artificial radioactive isotopes to the natural composition of the element.

In investigations with calcium, to which was added the isotope Ca^{45} , and with carbon enriched with C^{14} , appreciable isotopic effects were noted in plant assimilation of these elements. In the process of photosynthesis in a closed system, the specific radioactivity of carbon dioxide fell. The capacity of lowering the specific activity of carbon dioxide was particularly high in mature leaves of sugar beet, much less in the seedlings, and not evidenced at all in very young seedlings of the white lupine and corn. In cultivation of summer vetch in a medium containing radioactive isotope Ca^{45} , the specific activity of calcium in the plants was 27-39% lower than in the nutritive medium.

Study of the biological selective properties of plants in relation to the isotopes of one element warrants the most careful attention since it reveals new aspects of the processes of metabolism in the organisms and the special state of chemical elements in living matter.

The question of the isotopic effects in biological processes cannot be considered as conclusively settled. Further systematic investigations are still necessary.

Ukrainian Scientific Research
Institute of Plant Physiology

USE OF P^{32} IN THE STUDY OF NITROPHOSPHATE NUTRITION IN PLANTS IN THE INITIAL PERIOD OF DEVELOPMENT

L. A. Zuev and P. F. Golubeva

The radioactive isotope of phosphorus (P^{32}) was used as a tracer in study of nitrophosphate plant nutrition, chiefly in cultured grasses in the initial period of development. Observation was made on the absorption of labeled phosphorus from the nutritive solution by the seedlings in relation to conditions of feeding. In some seedlings, total phosphorus content was determined by the usual chemical method, as was the content of labeled phosphorus. The shoots and roots were analyzed separately, which made it possible to trace the distribution of the phosphorus in the seedling. Isolation and fractionation of phosphorus compounds allowed us to follow phosphorus metabolism in the shoots and roots.

Absorption of phosphorus in the etiolated seedlings of the majority of tested plants in the presence of nitrogen of the nutrient medium started quite early (after several days of germination) to lag behind absorption in the seedlings germinated with non-nitrogenous solutions. In the conditions of normal natural light, a reversal of the picture was observed.

Determination of total and labeled phosphorus in the fractions isolated from the shoots of fourteen-day-old winter rye showed that phosphorus is exchanged in the compounds of all the fractions. A part of the absorbed phosphorus was found in all fractions proportional to the total content of phosphorus absorbed. However, there was a fall in the degree of phosphorus exchange in the nucleoprotein fraction and the acid-soluble organic compounds in nitrogen-starved seedlings.

To bring out more clearly the dependence of phosphorus absorption and of phosphorus compound metabolism on the degree of nitrogen provision to the seedlings, short duration (7 days) germination of the seedlings in solutions of incomplete nutritive mixtures was carried out, enabling one to obtain seedlings with nitrogen and phosphorus impoverishment. The seedlings, on switching to solutions containing labeled phosphorus, were sharply characterized by their phosphorus absorption. Nitrogen impoverishment sharply reduced absorption of phosphorus. The seedlings, rich in nitrogen, but previously deprived of phosphorus, absorbed the phosphorus with great intensity. A direct relationship between intensity of absorption of phosphorus and synthesis of organic phosphorus compounds was observed.

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ABSORPTION OF P^{32} IN WINTER AND SUMMER VARIETIES IN RELATION TO THE STAGES OF ONTOGENESIS AND PLANT HARDINESS TO THE COLD

V. N. Razumov and N. D. Feofanova

The purpose of the investigation was to attempt, by means of labeled phosphorus, to assess types of agricultural plants by their resistance to cold, and also to find an indirect method of assessing winter varieties of grain grasses by the length of the stage of vernalization.

The energy of P^{32} absorption was determined in ten-day seedlings of a number of farm crops and of their varieties, using the nutrient solution at two different temperatures (+18° and +5°).

Absorption of labeled phosphorus from the solution differed at high (18°) and low (5°) temperatures in various varieties of winter wheat. The greater the resistance to frost of the variety, the higher the level of absorption of phosphorus by the seedlings at a low temperature. In the winter varieties not resistant to frost, a sharp fall in absorption of phosphorus was observed under the influence of reduced temperature. In this respect winter wheat varieties, not resistant to frost, approximated the summer varieties in which the greatest fall in phosphorus absorption at low temperatures was observed. The difference in absorption of phosphorus in the winter varieties is connected to a larger degree with the resistance of the plant to frost than with the duration of the vernalization stage. Analogous results were obtained in experiments with varieties of vetch, peas and barley. An attempt to apply this method in determining the frost resistance of varieties of clover and alfalfa did not give positive results.

The difference observed in phosphorus absorption by the seedlings of winter varieties and a number of crops may be used as an indirect method for detecting frost-resistant varieties.

Certain summer crops (corn, lentils, chick-peas, peas) from hilly regions, i. e., varieties more resistant to cold, also are capable of fairly energetic absorption of phosphorus (P^{32}) from the solution at a low temperature. The varieties from the same geographical regions but growing in valleys do not possess such a capacity.

The results of our experiments with the change in degree of absorption of P^{32} in conditions of lowered temperature indicate the existence of a general law. Phosphorus absorption is reduced to a lesser degree with reduction in temperature in varieties which originate and are distributed in lower temperature regions (winter varieties, varieties from hilly regions).

Determinations were made of the energy of absorption of labeled phosphorus in ten-day-old seedlings in wheat of varying winter capacity, cultivated from seeds vernalized to a different extent.

The results of the experiments showed that, in seedlings vernalized to a different extent and cultivated at 18°C, at the conclusion of the vernalization stage absorption of P^{32} fell sharply. This period is characterized by a heavy reduction in respiration energy.

Determination of the ratio of the values of absorption of P^{32} at low (6°C) and high (18°C) temperature $\frac{6}{18}$ shows that in the non-vernalized seedlings, the value of this ratio is high.

As vernalization activity is increased, the value falls, and at the end of the stage of vernalization reaches its lowest value. If the time of vernalization is prolonged (beyond the duration of the vernalization stage) the value of absorption remains constant.

The facts observed demonstrate significant changes in the course of the physiological processes at the moment of termination of the vernalization stage.

AIU-Union Institute of Plant Raising

USE OF RADIOACTIVE CARBON IN STUDY OF PHOTOSYNTHESIS IN Juglans SPECIES IN CONNECTION WITH THEIR CULTIVATION IN A NEW HABITAT

I. N. Kononov, E. N. Mikhaleva, F. L. Shchepot'ev
and A. I. Pobegailo

The work was carried out in 1955 in the Kupyansk agroforest nursery in the Kharkov region; the following walnut trees were investigated: J. manshurica Makh., J. regia L., J. nigra L. and J. cinerea L. The experimental plants were characterized by natural habitat and biological peculiarities. The manshurica walnut is prevalent in the mixed forests of the Far East, J. regia L. in the hilly regions of Central Asia, J. cinerea L. and J. nigra L. are found in our region only under cultivation. The more winter-hardy manshurica and cinerea walnuts grow freely in the central belt of European Soviet Russia. J. regia L. in the absence of acclimatization methods grows freely only in the south of our country. The nigra walnut occupies an intermediary position between these two types of plants.

The intensity of photosynthesis was calculated by means of a compound of radioactive carbon ($C^{14}O_2$) according to the method devised by O. V. Zolensky, O. A. Semikhatova and V. L. Voznesensky.

In all the Juglans species studied in our work the daily change in photosynthesis was of a uniform character. In the first half of summer it was characterized by two maximum values which in the second half of the summer tended to give a single peak curve.

The biological characteristics of the individual species were manifest in differences in intensity of photosynthesis and in the fact that the maximum values occurred at different hours of the day.

The period of the most intensive growth of the plants was accompanied, as a rule, by an increase in the energy of photosynthesis. The regia walnut, the most thermophilic tree of the Juglans species studied by us, was distinguished by a more protracted period of growth, and consequently showed increased assimilation capacity in the second half of summer. The manshurica tree, well adapted to the local habitat, completes its growth processes more quickly than do the other species, and consequently intensity of photosynthesis declines at an earlier stage. The cinerea tree shows similar behavior to the manshurica, and the nigra tree to the regia.

The tempo of plant growth and the indices of daily and seasonal change in photosynthesis may be of fundamental importance in evaluating the adaptability of the plants to the habitat.

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USSR Academy of Sciences

PROCESSES OF EXCHANGE BETWEEN STOCK AND SCION

K. S. Garnaga and F. L. Lesik

Labeled phosphorus was employed for rapid quantitative estimation of intergrowth of grafts. The work was conducted on intervarietal sunflower grafts, grafts of sunflower on lupine, and on apple tree grafts.

The experiments showed that the dynamic aspects of translocation of phosphorus through the site of grafting reflects the character of the intergrowth of the stock and scion union. With intake of phosphorus nutrients, the

intensity of phosphorus exchange between the stock and scion increases in proportion to the intergrowth of the components.

Botanical Institute, Academy of
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METHOD FOR DETERMINATION OF COMPATIBILITY OF SCION AND STOCK PLANTS WITH AID OF LABELED ATOMS

V. A. Tyrina

In fruit trees proper choice of stock is of great importance. A necessary requirement is compatibility of the grafted components. Testing of the stocks as a whole, and determination of compatibility as an essential part of the whole test require many years of work. Reduction in testing time would make it possible to solve more rapidly many questions connected with fruit growing.

In the search for a more rapid means of determining compatibility, the method of labeled atoms was used. It was assumed that the more compatible the grafted components, the more rapidly and to a greater extent would the labeled phosphorus introduced through the root system of the stock plant be detected in the crown of the grafted tree.

The test was performed with two varieties of apple tree, each of them grafted on two stock plants. It was known from previous investigations that of these varieties, "Amursk Harvest" develops best on "Ranet purple" stock, and the second, "Eastern Kitaiika", on Siberian apple tree stock.

Determination of the amount of labeled phosphorus in the leaves of the trees after intake of nutrient showed that in "Amursk Harvest," grafted onto "Ranet purple," the radioactive phosphorus penetrated from the root system into the aerial parts more quickly and in a larger amount than when the plant was grafted onto the Siberian apple tree. In the aerial parts of "Eastern Kitaiika" the labeled phosphorus was detected more quickly and to a greater extent when the plant was grafted onto the Siberian apple tree.

Despite the fact that the experiment was on a small scale, there was a distinct pattern of entry of labeled phosphorus from the stock to the scion. This gives grounds for assuming that, with suitable elaboration and pre-treatment, the use of labeled atoms can help to speed up determination of the compatibility of grafted components.

Far Eastern Branch of the USSR Academy of Sciences

PLANT METABOLISM

A. E. Fomin and N. K. Astakhova

In experiments on phosphorus and sulfur metabolism in plants, the method of non-root feeding was chiefly applied. The plants received the radioactive phosphorus or sulfur via the leaves or stem. The amount of radioactive substances in the various experiments was from 5 to 50 μ c per 1 ml. Analysis was made of the green leaves

developing anthers, seeds, pollen, root and rhizospheric soil.

In spring wheat and corn there is a relationship between the phosphorus metabolism in the shoots with foliar feeding and with the presence of reproductive organs—maturing pollen, and seeds in process of formation.

Before formation of the spadices, the main shoot of the corn transmits parts of the phosphorus from its leaves to the side shoot. Transmission of the substances in this period occurs also in a reverse direction, but more weakly.

During the latex-wax ripening of the corn translocation of phosphorus is subordinate to formation of reproductive organs. In this phase the phosphorus from the leaves moves to the anthers and seeds only within the confines of the side shoot or the main shoot. If the pollen has already ripened in the side shoot and it does not have its spadix, then the phosphorus from its leaves is transported to the spadices of the main shoot.

The roots of the main shoot and side shoot participate in the feeding of the whole plant. But the most active removal of nutritive substances from them occurs chiefly in those parts of the plant in which they are formed.

Corn side-shoot removal in the natural conditions of the Southeast, for varieties cultivated at present, does not represent a rational method.

The reproductive organs forming on any branch of the plant in the buckwheat, apple tree and oak, and the newly developing organs and tissues receive the plastic substances (phosphorus in our investigation) chiefly from those leaves which are to be found on the branch. Each branch of the plant can be fed through the leaves or stem independent of the others. This can be of great importance in cultivating and rearing new varieties of fruit trees along the desired lines.

The presence of exchange of substances (phosphorus and sulfur in our investigations) between plants with joint habitat is apparently widespread in nature.

Blue-green algae actively assimilate the products of plant metabolism. The nutritive substances taken from the soil are not fixed in the plant at every period of its life. In the processes of renewal of the organic compounds in the plant some of the substances return through the root to the soil. In the soil these substances enter into new chemical and biochemical (with participation of the microorganisms) transformations. After this they can again be utilized by the plants.

Thus, for certain nutrient elements there takes place a turnover between plants and soil. The proportions of such a turnover and its rate of recurrence depend apparently on the activity of the biochemical processes in the plant, the physiological role of the element, and the conditions of cultivation and growth of the plant.

Southeast Agricultural
Scientific-Research Institute

EFFECT OF RADIATION ON OXIDATION-REDUCTION PROCESSES IN THE PLANT ORGANISM

M. G. Abutalybov and N. B. Vezirova

We made an experimental study of the influence of radioactive isotopes of phosphorus and iron on the growth, development and metabolism of plants (100 μ c per one plant). Cotton, corn, tomato and the eggplant were studied.

In the report, data are given characterizing the influence of radioactive phosphorus and iron isotopes on the oxidation-reduction processes in various parts of the investigated plants. In the leaves and fruits, a study was made of catalase activity—peroxidase, polyphenoloxidase—and the total iodine-reducing capacity of these organs was studied.

As a result of the investigations conducted, it was found that the radioactive phosphorus and iron isotopes enhance the acceleration of growth and development and increase plant yield.

The radioactive isotopes of phosphorus and iron exert a highly positive influence on the increase in catalase activity in the leaves and fruits of tomatoes, eggplants and cotton.

Under the influence of radioactive isotopes of phosphorus and iron, a considerable increase in over-all reducing activity in the leaves of the tomato and of the eggplant was observed, as well as increase in the activity of polyphenoloxidase in the leaves and fruits of tomatoes and eggplants, and increase in the activity of peroxidase.

The increase in catalase activity and reduction capacity of the leaves is apparently related to the increase in activity of dehydrogenases with low doses of radioactive isotopes.

Azerbaijani Agricultural Scientific-Research Institute.

FUNCTIONAL SPECIFICITY OF PHLOEM AND PHELLODERM IN PLANTS

V. O. Kazaryan

The attention of investigators has for a long time been attracted by the presence of chlorophyll in phellogen cells adjacent to the phloem in shoots and branches of plants. The essential role of this tissue, despite extensive work, is still not altogether clear.

Application of radioactive carbon dioxide and glycine established that the phellogen cells carry on photosynthesis, a function of green tissues, with great intensity in normal conditions.

Here it is not atmospheric carbon dioxide which serves as the basic source of carbon dioxide for photosynthesis in the chlorophyll-bearing phellogen, but the intratissue gas evolved in the intensive respiration of phloem cells. The oxygen thereby evolved is rigorously absorbed by the cells of the cyto-like phloem tubes, ensuring their energetic respiration, as a result of which their normal function of translocation of nutritive plastic substances is performed.

The results of experiments with stems of climbing plants provide evidence on the nature of activation of assimilate translocation in the phloem. In these experiments it was established that the speed of translocation of radioactive glycine administered through the lower end sharply differs in the peduncles in conditions of light and dark. In conditions of light the speed of translocation of this substance was four times greater than in the dark.

In the normal functioning of the phloem, in addition to intratissue oxygen, atmospheric oxygen also plays a part, entering through the stem lenticels. This ensures translocation of the assimilates along the stem in night hours, when the photosynthetic activity of the phellogen has ceased, and also through the root system where green plastids are completely absent.

The chlorophyll-bearing cells of the stem moreover, by assimilating the intratissue acid for synthesis, completely compensate for the loss in plastic substances used by the phloem cells as respiratory material. This is another function, not without importance, of the chlorophyll of plant stem tissues.

Formation of chlorophyll in the cells of meristematic tissue of the stems of grain grasses at the commencement of ear formation is also bound up with photoreduction of carbon dioxide, as a result of which oxygen, necessary for energetic growth and cell division is evolved. Both nonvernalized and short-day plants do not form chlorophyll in the embryonic cells.

Also related to this is the normal union of the components of grafts in those cases where corresponding conditions of chlorophyll formation are present in the plant stems. In darkness union of the components of herbaceous

grafts is always made difficult or is even precluded as was shown by N. V. Tsitsin.

Botanical Institute, Armenian SSR Academy of Sciences.

ENTRY AND DISTRIBUTION OF P^{32} AND C^{14} IN PLANTS IN CONNECTION WITH THEIR ELECTRICAL POLARITY

V. A. Opritov

Plant electrophysiology has disclosed a number of important characteristics of the metabolic bioelectrical potentials (BEP). Yet the question as to what role these potentials play in the vital activity processes in plants and, in particular, in entry and transport of substances has been practically untouched on experimentally.

In the investigations conducted, we started from the hypothesis that one of the sources of energy of the work executed by the plant in the accumulation and transport of substances is the electromotive forces of the cells and tissues.

The experiments involved the study of entry and distribution of radioisotopes, P^{32} and C^{14} , in tomato and wheat in relation to various influences, with single measurement of the plant electrical polarity. The work was conducted in three successive stages.

As a result of the first stage of the investigations, it was established that there exists wide agreement in the effect of heteroauxins on electromotive force and on the entry and distribution of P^{32} and C^{14} in tomato plants. This suggested a possible close link between the electrical polarity of cells and tissues and the processes of absorption and transport of substances.

The experiments in the second stage of the investigations showed that an indirect change in bioelectrical potential difference in tomato seedlings resulting from treatment of a small section of their apex or base with 5×10^{-4} M CdCl₂ solution leading to a significant change in the entry of P^{32} in the plant. Higher entry of P^{32} corresponds to a more negative potential difference. This last factor may to a certain degree be connected with the electrical properties of the form of phosphorus transported within the plant.

Finally, in the third stage of the investigations it was found that a direct influence on the potential difference by means of addition to the stalks of the tomatoes and wheat of fine cotton wool wicks moistened in liquid conductors (0.01 M NaCl solution in tap water), by causing escape of surface metabolic bioelectrical potentials in the seedlings, at the same time considerably reduces entrance of P^{32} . This strongly suggests that the electromotive forces must play a definite part in entry and transport of substances in plants.

It is assumed that there may be several ways in which plant potential differences participate in entry and transport of substances (ion, adsorption, electrophoresis, electroosmosis, electrical transfer of ions, etc.). Study of all the possible ways of such participation with accurate assessment of energy transformations in the organism is one of the most important tasks in biological physics.

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USE OF ISOTOPES IN STUDY OF FLOWERING AND NECTAR SECRETION IN THE LIME TREE

D. V. Girink

The lime, the chief nectariferous tree of the Far East, does not blossom and produce nectar annually. In investigation of the question of the periodic blossoming and nectar secretion of limes, we set ourselves the task of elucidating the participation of reserve substances and of fresh assimilates in nectar formation.

As a result of the method of ringing lime tree branches, the hypothesis has been advanced that the basic source of material for nectar production in the lime tree is the fresh assimilates produced by the leaves in the process of photosynthesis in the period of blossoming. In order to shed light on this question and also on the question of the entry of the assimilates in fruits situated in the axils of damaged leaves we used $C^{14}O_2$.

To this end the leaves were kept in an atmosphere of $C^{14}O_2$. On the next and following four days, radioactivity was determined in the nectar collected from the blossom of the inflorescence located in the axil of the fed leaf and from the inflorescences located in the axils of the leaves lying above and below.

In addition, after blossoming of the limes, $C^{14}O_2$ was again given to the other leaves and on the next and following two days fruits from the inflorescences in the axils of the fed leaf were taken, and also from those situated in the axils of the excised leaves. The radioactivity of the fruits was determined. The results of these determinations show that in the process of formation of nectar the lime flowers utilize the fresh products of photosynthesis manufactured by the leaves in the period of blossoming; the assimilates from the leaf in the main enter the flowers and fruits of the axil inflorescence; the inflorescence situated in the axil of a damaged leaf develops on account of assimilates entering from other leaves; entry of radioactive carbon, assimilated in 30 minute feeding of the leaf with marked carbon dioxide into the nectar of the flowers and lime fruits, lasts for several days.

Far Eastern Branch of the USSR Academy of Sciences

RESTORATION OF THE AMINO ACID COMPOSITION OF BRAIN ALBUMINS

G. E. Vladimirov, G. A. Nechaeva, N. V. Sadikova,
V. A. Skvortsevich and A. P. Urinson

1. Using methionine, labeled with radioactive sulfur, and also glycine, glutamic acid and tyrosine, labeled by radioactive carbon, one can characterize the rate of incorporation of labeled amino acids in the brain albumins and thereby characterize the rate of synthesis of albumins in such a specialized functional organ as the brain.

2. Penetration of the labeled glycine in the large cerebral hemispheres proceeds at a slower rate than in midbrain, cerebellum and spinal cord.

3. The process of substitution of glycine and the amino acids formed from it occurs more actively in the albumins of the cerebellum and large cerebral hemispheres, and is less intensive in the albumins of the midbrain and spine.

4. Restoration of amino acid composition occurs in all the basic albumin fractions of the brain, but its speed in the various fractions is not uniform; the most intense restoration occurs in the water-soluble albumins and it is slowest of all in the albumins of the residue not extracted by alkaline solution.

5. Using tyrosine marked by radioactive carbon, it proved possible to evaluate the mean duration of retention of the integral albumin molecules in brain tissue.

6. Functional state affected the intensity of amino acid metabolism of the brain; with excitation, an insignificant increase was found, with narcotic sleep, a distinct fall. Hypothermia had an exceptionally marked effect on amino acid metabolism; fall in the intensity of this metabolism was expressed much more sharply than fall in metabolism of phosphorus compounds.

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EVOLUTION OF THE PROCESS OF OXIDATIVE PHOSPHORYLATION IN THE BRAIN AND FORMATION OF BLOOD-BRAIN BARRIER IN A NUMBER OF VERTEBRATES

N. A. Verzhbinskaya

In the present work the speed of turnover of ~P bonds in the brain of the representatives of all classes of vertebrate animals was studied.

The "turnover time" was calculated, i. e., time of a single decomposition and resynthesis of an amount of ~P contained in ATP normally present in the brain.

It was found to be 75-90 min in the brain of a fish, 48 min in the brain of a frog, 16 min in turtles, 12 min in a pigeon, and 8 min in rats. The "speed of turnover" of PATP was 2.3 μ moles of P in one hour per 1 g fish brain, 4.0 μ moles in frog, 14 μ moles in turtles, and 37-66 μ moles in warm blooded animals.

The water vertebrates were sharply divided from land ones in rate of brain respiration in vitro (previous data) and in speed of turnover of ~P bonds of ATP in vivo. In a number of vertebrates there is an increase in the P:O coefficient calculated on the basis of the data of "speed of turnover" of TP in the brain in vivo and the corrected data of the earlier work on brain respiration in vertebrates in vitro. Its minute value in the water vertebrates testifies to the absence of coupling of brain respiration with phosphorylation. In land vertebrates, in the metabolism of the intact brain respiration is coupled with phosphorylation to a smaller degree than in the experiments in vitro.

The low absolute value of OUR-NF* of the brain and its exceptionally slow increase in time product the idea of exceptionally slow penetration of NF* from the plasma into the brain. This conception requires re-examination.

In evolution of vertebrates, the "visible" (according to the data of OUR-NF* of the brain) speed of penetration of P³² from the blood into the brain decreases. In fish it is relatively high and sharply exceeds the speed of inclusion of P³² in the labile phosphates of the brain. In land classes the speed of penetration of P³² in the brain is lowered and corresponds to the speed of incorporation of P³² in the labile phosphates of the brain.

Hence, one can conclude that the blood-brain barrier is absent in fish and developed in land forms.

Another conception is gained in reviewing the speed of increase in time of UR* in the brain.

UR-NF* of the brain increases only at the outset of the experiment, 30 min in cold blood and 10-15 min in warm blooded animals. During this period, the UR-NF* of the brain reaches the threshold value and does not exceed it during the remainder of the experiment.

There are grounds for considering this UR-NF* threshold as an equilibrium with the blood plasma.

* Abbreviations marked with an asterisk have been transliterated, as it was not found possible to determine their significance from this brief abstract. ~P* is in all cases undoubtedly phosphorus or phosphorus compounds.

The facts described encourage acceptance of the sorption theory of cellular permeability as explaining the mechanism of the functions of a blood-brain barrier. From the point of view the sorption theory of cellular permeability the speed of penetration of P^{32} from the blood to the brain is just as high as in the other tissues and is determined by the speed of the process of phosphorylation in the brain.

The point of view elaborated does not imply recognition of the existence of a special structure in the brain performing the function of a barrier. The function of the blood-brain barrier in relation to phosphorus is localized in the neurones and other cellular elements of the brain which consume phosphates in metabolism.

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PRELIMINARY RESULTS OF STUDY BY ISOTOPIC TECHNIQUE OF CERTAIN FUNCTIONS OF THE ORGANISM WITH SURGICAL DAMAGE OF THE VARIOUS PARTS OF THE CENTRAL NERVOUS SYSTEM

E. A. Asratyan, I. K. Zhmaklin and G. G. Musalov

By means of radioactive isotopes of bromine and calcium new data were obtained on the role of the cerebral cortex in unconditioned reflex regulation of various functions of the organism, and the consequences of surgical damage to the spine on the state and activity of the various sections of the central nervous system and the effector organs connected with them.

In the first series of experiments in decorticated dogs (unlike normal ones), retardation of absorption of amino acids from the gastrointestinal tract in the first hours after the introduction of the labeled compound was observed.

The process of disappearance of the labeled compound from the blood of the decorticated animals also developed more slowly than in the controls.

In the second series of experiments it was established that trauma of the spine in dogs leads to extensive functional disturbances in the central nervous system not only below, but also above the site of transverse section, and also in the organs and tissues innervated by the corresponding sections of the spine. This was expressed in change in the intensity of incorporation of radioactive isotopes of bromine and calcium.

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PATHS OF TRANSMISSION OF CORTICAL INFLUENCES ON THYROID GLAND

M. G. Amiragova

1. In investigations on dogs the influence of the functional state of the cerebral cortex on the phases of synthesis and secretion of thyroid gland hormone, and also the paths of transmission of these influences were studied. The functional state of the central nervous system was changed by means of conditioned defense re-

flexes. The activity of the thyroid gland was evaluated by the absorption of radiiodine and secretion into the blood of the products of the vital activity of the gland.

2. It was established that under the influence of positive conditioned defense reflexes absorption of radiiodine by the thyroid gland falls and secretion of the products of its vital activity is stimulated. Differential inhibition contributes to accumulation of radiiodine in the thyroid gland.

3. To clarify the question as to whether the pituitary is in fact always the sole regulator of the secretory activity of the thyroid gland, investigations were performed with hypophysectomy in dogs. These investigations showed that the cerebral cortex may influence the thyroid gland without the pituitary being involved.

4. Experiments conducted on dogs on the one hand after removal of the suprarenal, and on the other after transverse section of the *n. splanchnici* major, showed that even in these conditions the cortical impulses reach the thyroid gland.

5. In the light of these investigations it was necessary to re-examine the conception held by some authors on transmission of nerve impulses from the central nervous system to the thyroid gland along direct nerve routes. For this purpose, experiments were conducted on dogs without a pituitary and without one suprarenal gland, with transverse section of the *n. splanchnici* major in the other. In such animals transmission of cortical influences to the thyroid gland vanished completely.

6. In realization of cortical influences on the thyroid gland, the presence of either the pituitary or the suprarenals was necessary. Consequently, cortical influences on the activity of the thyroid gland are transmitted by the neurohumoral route.

Institute of Normal and Pathological Physiology

COMPARATIVE STUDY OF THE SPEED OF INCORPORATION OF P^{32} IN PHOSPHORUS COMPOUNDS OF THE NERVOUS SYSTEM

E. B. Skvirskaya and T. P. Silich

The object of the work was to study metabolism of phosphorus-containing albumins and phospholipids (PL), their link with other substances in the different functional parts of the nervous system and in certain nerve cell structures.

At first, the rate of metabolism of a number of phosphorus-containing compounds of the tissues of the grey and white matter of the brain, cerebellum and peripheral nerve (sciatic) of cats was determined.

In investigation of the metabolism of phosphorus compounds with the use of radioactive phosphorus (P^{32}), we succeeded in demonstrating the greater speed of incorporation of P^{32} in "true" RNA and PL of the cerebral cortex in comparison with white matter and the cerebellum. Incorporation of P^{32} in RNA of the sciatic nerve was somewhat higher than in the various parts of the central nervous system.

Thus, the investigations revealed biochemical features for the various parts of the nervous system closely associated with differences in structure and function. They allow one to conclude that the cerebral cortex - a formation phylogenetically later and functionally more complex - is characterized by a higher content and increased level of metabolism of a number of phosphorus compounds, which indicates their important biological role.

Subsequently, a study was made of the nucleoproteins and their metabolism in various structural parts of the nervous system.

With the aid of a phosphorus isotope we succeeded in showing, in addition to differences in content, non-uniform metabolism of the same phosphorus components of the different fractions.

The features of metabolism of phosphorus compounds of the various fractions were similar for the different parts of the brain; however, there were quantitative differences.

Proceeding from the conceptions of the relationship of structure to function and chemistry, one could assume that the differences established for the fractions (with this means of treatment) depend on the structural part of the nerve cell with which the various nucleoproteins are associated, in particular, that the high activity in RNA metabolism found in the residue is determined by the great speed of incorporation of P^{32} in nuclear RNA. As a result of the investigation of pure nuclei obtained from the large cerebral hemispheres of cats this hypothesis was confirmed.

Thus, comparative investigations carried out with radioactive phosphorus made it possible to show differences in metabolism of the same phosphorus compounds depending on the morphological structures with which they are connected. This, in turn, may indicate their diverse functional significance in the nervous system.

Institute of Biochemistry Ukrain. SSR
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RATE OF INCORPORATION OF P^{32} IN BRAIN PHOSPHORUS COMPOUNDS AND SPEED OF THEIR RENEWAL IN PARABIOTIC STATE

I. A. Medyanik

The purpose of the investigation was to ascertain the rate of incorporation of P^{32} in the brain phosphorus compounds and to establish the speed of their renewal during the development of a parabiotic condition. For this object experiments were conducted on frogs which received P^{32} intraperitoneally at the rate of $0.5 \mu\text{C/kg}$ body weight in the form of Na_2HPO_4 solution. At varying time intervals (2, 2½, 3, 3½ hours) following administration of P^{32} a direct 1.5 ma electric current with definite direction (ascending or descending) was passed through the central nervous system of the animals. Current was passed throughout the four hours of the experiment. Specific suspensions of the brain were ground with 10 ml 4% trichloroacetic acid solution. After centrifugation, the amount of phosphorus in the lipid-albumin complexes was determined in the sediment. The centrifugate was divided into the inorganic phosphorus and acid-soluble fractions. The phosphorus content in all three fractions was determined by the method of Fiske and Subbaroy. The activity of P^{32} in imp/min per ml of each fraction was measured by means of a cylindrical counter of the B-2 type.

The results of the observations showed that in frogs with weak reflex activity the specific activity of the phosphorus of the inorganic phosphate, the acid-soluble and lipid-albumin fractions was low. In animals with raised reflex activity a high specific activity of the phosphorus of all three fractions was noted. The speed of renewal of phosphorus in the brain phosphorus compounds was higher in animals with increased reflex activity. The relative specific activity of the phosphorus of the acid-soluble fraction was 5.2 in these animals, and 4.0 of the lipid-albumin fraction, while the corresponding values in animals with weak reflex activity was 1.5 and 0.3. Thus, the exchangeability of the brain phosphorus compounds was low when the reflex activity of the nervous system was weakened, and rose sharply with intensification of the work of the brain.

The results of the second series of experiments showed that two-hour anode polarization of the brain at first (in the first hour) reduces and then (in the second hour) increases the speed of incorporation of P^{32} in the brain phosphorus compounds.

Under the prolonged action on the brain of the cathode of the direct current we observed a sharp increase in the specific activity of the phosphorus of the acid-soluble and lipid-albumin fractions in the first hour of the experiment and a gradual fall to the original values during the second hour.

Consequently, the emergence of a parabiotic state in the nerve cells induced by the prolonged action of a direct and alternating current was accompanied by a difference in the rate of P^{32} incorporation in the brain phosphorus compounds.

The relative specific activity of the phosphorus of the acid-soluble and lipid-albumin fractions changed in accordance with the phase changes in the excitability of the cortical cells (increase, fall) under the influence of a descending direct current on the brain. It rose in the first one and a half hours during which the current was applied and gradually fell to the original values.

With a prolonged effect on the brain of the cathode of the direct current, the relative specific activity of the phosphorus of the acid-soluble and lipid-albumin fractions in the first half hour during which the current was applied increased sharply, but, during the second hour of the experiment, dropped to or below the original level.

The observed regularity in the changes of the speed of renewal of phosphorus in the brain phosphorus compounds appeared more rapidly under the action on the brain of the cathode than of the anode of the direct current. Consequently, the observed increase in excitability of the nerve cells in the first phase of parabiosis is characterized by intense phosphorus compound metabolism in the brain, while its fall in the second phase is associated with decreased metabolism of these compounds in brain tissue.

Lvov State University

METABOLISM OF PHOSPHORIC ESTERS OF CHOLINE AND ETHANOLAMINE IN THE BRAIN

P. A. Kometiani, L. K. Tkeshelashvili and T. A. Ovsyanko

The investigation was initiated as a result of discovery of the fact that in the process of synthesis of acetylcholine in brain preparations, phosphorylcholine is formed by means of direct phosphorylation of choline.

In order to solve the question of the direct utilization of phosphorylcholine and phosphorylethanolamine in the synthesis of phospholipids, phosphorylcholine and phosphorylethanolamine with labeled phosphorus atoms were synthesized. In experiments on dogs and rabbits 5 hours after suboccipital, and 18 hours after subcutaneous administration of the labeled compounds, the animals were killed, the brain extracted, and the phosphorus compounds in it analyzed. The control animals, instead of labeled phosphorylcholine and phosphorylethanolamine, received labeled inorganic phosphate.

It was found that the sum activity of the phospholipids after administration of the labeled phosphorylcholine and phosphorylethanolamine was approximately uniform with the value obtained after administration of labeled inorganic phosphate in analogous conditions. The activity of phospholipidcholine in experiments with administration of phosphorylcholine and also the activity of phosphatidylethanolamine in experiments with administration of labeled phosphorylethanolamine was always higher than the value obtained in the experiments with labeled inorganic phosphates. Hence, one may conclude that phosphorylcholine and phosphorylethanolamine may be utilized in synthesis of the corresponding phospholipids.

The possibility of direct utilization of phosphorylcholine and phosphorylethanolamine in the synthesis of phospholipids was checked in experiments with brain homogenates. These experiments gave negative results probably because the optimal conditions of synthesis were not selected.

Bearing in mind the fact that acetylcholine greatly enhances incorporation of labeled inorganic phosphate in the phospholipids, experiments were conducted to elucidate the influence of phosphorylcholine on this process. The findings obtained showed that, on the contrary, phosphorylcholine inhibits incorporation of inorganic phosphate.

Institute of Physiology
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STUDY OF THE INFLUENCE OF ADRENALIN ON THE FIXATION OF CARBON DIOXIDE IN THE ANIMAL ORGANISM

B. N. Stepanenko and I. Z. Sergienko

In several earlier papers it was shown by means of deuterium and then C^{14} that in hungry animals certain small doses of adrenalin stimulate synthesis of glycogen from molecules with shorter carbon chains than glucose. This synthesis was accompanied by incorporation of $C^{14}O_2$ to a considerable degree.

In unravelling the mechanism of this process the following problems were involved: 1) whether there is a link between the increase in CO_2 incorporation in glycogen under the influence of adrenalin and its generally known glycemic effect (introduction of glucose and $NaHC^{14}O_3$ in the starving animals was used to obtain a preparation of glycogen and glucose marked with C^{14} at the 3 and 4 positions); 2) the position of the labeled carbon in the glucose molecule when glycogen synthesis is stimulated by adrenalin.

Rats, starved for 24 hours, were injected intraperitoneally with $NaHC^{14}O_3$ (about $20 \mu c$ per 100 g body weight). In addition, in one experimental series, simultaneous with the sodium bicarbonate, glucose varying in amount from 200 to 750 mg/100 g body weight was administered to the rats. In the second experimental series, adrenalin and glucose were given together with $NaHC^{14}O_3$ (in the same amounts). The glycogen was isolated from the rat liver at the end of three hours. The radiobiochemical yield was estimated on the basis of glycogen output and its specific activity.

On administration of increasing doses of glucose, and also of adrenalin and glucose (i. e., in both variants of the experiment), with a steady increase in glycogen yield, the radiobiochemical output reached the maximum, and then considerably fell.

The maximum radiobiochemical output in the experiments with administration of adrenalin and glucose considerably exceeded the maximal output obtained in experiments with any quantity of glucose (without adrenalin). This indicates that stimulation of carbon dioxide fixation by adrenalin cannot be merely attributed to the glycemic effect.

Determination of the position of the radioactive atoms in glucose, obtained with the action of adrenalin, performed fundamentally according to Topper and Hastings, and also Koshland and Westheimer, showed that the labeled atom is principally found in the third and fourth positions.

The data obtained enabled us to improve on the technique of biosynthesis of 3,4- C^{14} glycogen and crystalline 3,4- C^{14} glucose by means of the animal organism, making it possible to obtain a higher radiobiochemical output than with the most widely applied method of Arnshtein and Bentley.

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RATE OF METABOLISM OF GLUTAMINE AMIDO NITROGEN IN MUSCLES AND LIVER

D. L. Ferdman and A. I. Silakova

The investigations carried out established that within 1 hour 40 min after intravenous injection of large doses of ammonium salts (30-45 mg ammoniacal nitrogen with a content of 9.7 atomic percentage N^{15} per 100 g body weight) in the skeletal muscles, the ammonia content rises by 18% and that of glutamine by 39.2%. Simultaneously applied mass-spectrometric measurements * of the distribution of the stable isotope of nitrogen in various nitrogen groups of muscles showed that its concentration is particularly high in the glutamine amido nitrogen group. N^{15} enrichment of the nitrogen of this grouping is, on average, of the order of 11.5 times, corresponding to 41.3% of the degree of its renewal. Ammoniacal nitrogen at the same time is enriched only 6.2 times, i. e., the degree of its enrichment is only 20.6%.

The data obtained allow one to draw a conclusion on the rate of renewal and consequently on active participation of the glutamine amido nitrogen in tissue nitrogen metabolism.

* Mass spectrometric measurements were conducted by us in the L. V. Pisarzhevsky Institute of Physiological Chemistry of the Academy of Sciences of the Ukrainian SSR.

This conclusion was confirmed by data obtained in experiments of short duration (10 min after introduction of the ammonium salt) when the glutamine content was still unchanged, although the degree of its renewal had already reached, on average, 19.8%.

It was seen that with passage of time concentration of N^{15} is reduced in the skeletal muscles in the ammonium nitrogen and increased in the glutamine and albumin amido nitrogen. These values, 10 min after administration of the ammonium salt, were respectively — 3.53, 2.20 and 0.388 atomic percentage of N^{15} and after 1 hour 40 min respectively — 2.31, 4.20 and 0.466 atomic percentage of N^{15} .

The results obtained demonstrate the participation of the albumin and glutamine amido nitrogen in the processes of ammonia metabolism. Since an appreciable increase in the excess of atomic percentage of N^{15} in the muscle albumin amido nitrogen occurs only at later time intervals following administration of ammonium salts, it may be taken as an indication of the later, as compared with glutamine amido nitrogen, incorporation of this group in renewal of the ammonium radical in the muscles.

Similar findings were established with introduction of much smaller (3-4 times) amounts of ammonium salts in the organism. Even in these conditions (low ammonium level in the tissues) N^{15} concentration in the glutamine amido nitrogen was higher (1.30 atomic percentage) than in the ammonium nitrogen (1.12 atomic percentage).

It was found that the ammonium radical is particularly concentrated in the liver. Thus, 1 hour 40 min after intramuscular injection of an ammonium salt, 3.9 atomic percentage of N^{15} was found in the ammonium content of the liver. The content of N^{15} was twice as high in the glutamine amido group (2.58 atomic percentage), and more than 4 times as high in the albumin amido nitrogen group (0.52 atomic percentage) than in the muscles.

It was further established that the regularity of pattern characterizing participation of the glutamine amido nitrogen in tissue nitrogenous substance metabolism on starvation is akin to that in the tissues of control (non-starved) pigeons, but quantitatively much higher.

The results of the investigations show that the glutamine amido nitrogen is an active participant in tissue nitrogen metabolism.

Institute of Biochemistry
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PARTICIPATION OF COENZYME-A DERIVATIVES IN PHOSPHORUS METABOLISM IN THE ANIMAL LIVER

A. V. Kotelnikova

When rats are given radiophosphorus, a substance is recoverable from the Ba insoluble salt fraction of the liver by means of paper chromatography, possessing considerable radioactivity and absorbing ultraviolet light but not identical to the components of the adenyl system — ATP, ADP or AMP.

The investigation of the eluates of the spots of this substance in ultraviolet light showed that the absorption curve has a maximum at 260 mμ, and is characteristic of adenine or uridine compounds. The reaction with bromine water, specific for uridine derivatives, proved to be negative; therefore, the compound should rather be included among the adenine nucleotides.

Hydrolysis of the Ba- insoluble salt fraction from the liver of rats and also the eluates from the spots of the unknown compound, and of the purine and pyrimidine bases confirmed the presence of adenine and the absence of uracil.

The investigated compound gave a positive S-S-group result in the nitroprusside test in the presence of KCN, but did not contain free-SH groups. On the basis of this reaction and also the ultraviolet absorption curve the compound was tentatively classified as a derivative of coenzyme-A.

This hypothesis received direct confirmation in experiments with enzymatic acetylation of aminoazobenzol: both the Ba insoluble salts fraction from rat liver, and the eluate of the spots of the S-S compound display distinct coenzyme-A activity. On the basis of this, the S-S compound is either a S-S coenzyme-A or some other derivative of coenzyme-A.

Determination of the specific activity in the spots of ATP, ADP, AMP and the S-S compound from the purified Ba- insoluble salts fraction of rat liver, obtained at short time intervals after administration of radiophosphorus (15-30 min.), showed that the S-S compound possessed high specific activity, only slightly below that of ATP and ADP.

The high specific activity of the S-S compound points to its active role in the phosphorus residue transfer in the liver; the role of phosphate carrier has not previously been assigned to coenzyme-A.

It could have been assumed that the radioactive derivative of coenzyme-A found in the liver may be phosphorylcoenzyme-A, however, on the basis of the preliminary data, the substance is not phosphorylcoenzyme-A.

Laboratory of Physiological Chemistry
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ROLE OF BROMINE IN THE ANIMAL ORGANISM

I. N. Verkhovskaya

In the animal organism bromine is found in the ionic form, with the exception of the thyroid gland, where a small part is bound with the albumins.

The distribution of freshly administered bromide in the various organs and tissues of the investigated animals (rats, guinea pigs, rabbits and dogs) was specific; usually the majority of the bromine was found in the thyroid gland, in the medullary layer of the kidneys, in the blood, and in the stomach mucosa. Average quantities were found in perives, pituitary, liver, spleen, cortical layer of the kidneys, and in the suprarenals. The smallest amount of bromine was in the various sections of the brain and in the muscles.

Bromine in the animal organism originates in oral intake. There is no bromine depot. The hypothesis on a connection between the type of nervous system and varying blood bromine content is groundless.

Sex or age did not influence human blood bromine content.

Distribution and rate of metabolism of bromine in the various sections of the brain (within limits of experimental error — 10%) did not change in various functional states of the central nervous system caused by strong physical fatigue, insomnia of varying duration, sleep and strong excitation (induced by Medinal and phenamine) and also by a convulsive state and coma, induced by passage of an electric current through the animal brain.

Bromine metabolism in the thyroid gland is specific.

With thyrotoxicosis in humans as with hyperthyroidism in guinea pigs, the bromine content in the thyroid gland is somewhat above normal.

Under the influence of methyl thiouracil, the total amount of bromine entering the thyroid gland increases. This is connected with hyperplasia of the thyroid gland induced by methyl thiouracil. This is accompanied by

slowing down of bromine incorporation in the albumin fraction of the thyroid gland.

Introduction of bromides in the animal organism influences iodine metabolism and produces changes in the morphological and functional state of the thyroid gland.

Institute of Biophysics
USSR Academy of Sciences

CERTAIN CHARACTERISTICS OF ENERGY EXCHANGE IN LEUCOCYTES

I. S. Lukanova, I. F. Seits and V. I. Teodorovich

Literature on the biochemistry of leucocytes is very contradictory. In particular, sufficient light has not so far been shed on the question as to which of the energy-producing processes—respiration or glycolysis—underlies the functional activity of the white blood cells. Some authors consider that it is respiration, others glycolysis. Even less clear is the question of the origin and biological purpose of aerobic glycolysis which is peculiar to certain groups of leucocytes.

Yet, study of these features of metabolism in leucocytes may be of important significance for understanding the biology of these cells and their role in various pathological states, above all, in diseases of the blood system.

Normal leucocytes and leucocytes from blood of persons suffering from chronic myeloid leucosis, having much in common, revealed certain features of metabolism also peculiar to cancerous cells. These features are: 1) the presence of a high aerobic glycolysis (~60% of the anaerobic one), i. e., incomplete Pasteur effect; 2) inhibition of cell respiration (~30%) on addition of glucose, i. e., "reversible" Pasteur reaction; 3) complete resynthesis of ATP in anaerobic conditions, at a rate not inferior to the rate in presence of air.

The presence of these features of energy exchange, common not only to cancerous cells, but to leucocytes, allows one to conclude that they are not specific for malignancy and that there is no casual relationship with malignant processes.

Quantitative determination of O_2 absorption, formation of lactic acid in aerobic and anaerobic conditions, and comparison of these data with the amount and speed of the metabolic transformation of ATP enabled calculations to be made indicating the leading role of glycolysis in supply of energy to leucocytes. This point of view is strengthened by experiments with "uncoupling" poisons (dinitrophenol, methylene blue, etc.) which disturb respiratory phosphorylation in aerobic cells, but do not affect resynthesis of ATP in the leucocytes. On the other hand, the glycolytic poison monobromosuccinate, while not suppressing respiration, produced a sharp fall in the amount of relative specific activity of ATP labile phosphorus.

The data obtained point to the absence of a link between the depression of leucocyte respiration and energy balance. This conclusion was confirmed by calculations for all the investigated groups of white blood cells, but was especially demonstrated for blood leucocytes of patients with acute leucosis. In this case, aerobic glycolysis was 90–95% of the anaerobic level. With a transition from anaerobic conditions to aerobic ones, glycolysis, ensuring complete resynthesis of ATP in anaerobic conditions, was reduced as a whole by 5–10%, but very intensive respiration appeared, which sharply increased the total energy output and may have ensured phosphorus esterification, greatly exceeding the maximum possibilities of the glycolytic mechanism. Nevertheless, both the amount and the relative specific activity of ATP phosphorus remained practically unchanged. Apparently, respiration in the leucocytes is essentially associated with some other function not connected with energy.

The lymphocytes were subjected to a similar investigation.

In these cells aerobic glycolysis and "reversible" Pasteur reaction was not found. However, in this case the

complete resynthesis of ATP was ensured in anaerobic conditions just as in aerobic medium.

The Leningrad Red Banner of
Labor Scientific Research
Institute of Blood Transfusion

SPEED OF INCORPORATION OF RADIOMETHIONINE (S^{35}) IN ALBUMINS OF GASTRIC GLAND IN RELATION TO THEIR FUNCTIONAL STATE AND TOPOGRAPHY

E. E. Martinson, L. Ya. Tyakhepyid
and A. Ya. Lind

1. In experiments on cats with excitation of gastric secretion by food intake, acceleration of albumin "renewal" and synthesis in the glands of all sections of the stomach was seen.

2. The results of the experiments showed that the speed of "renewal" of albumin in the mucous membrane of the various sections of the stomach (pylorus, greater and lesser curve) was different. Incorporation of methionine proceeds with greater speed in the glands of the lesser curve, both with functional rest and with digestive excitation.

3. In absolute value the speed of "renewal" of the albumins of the glandular cells in the pyloric zone was the least, but here, in the period of excitation of secretion, it increased, which obviously reflects intensification in the pylorus of synthesis of albumin-type hormonal products.

4. Increase in the speed of incorporation of methionine in the albumins of the gastric glands was caused by an intensified supply of methionine in the glandular cells as a result of hyperemia in the period of secretion. This is borne out by the results of experiments with histamine which induces strong hyperemia. Gastric secretion, induced by histamine, in contrast to excitation by food, was accompanied not by an intensification, but by a distinct fall in the speed of incorporation of methionine in the albumins of the glands in all gastric sections.

5. The results obtained show that the method of investigation of the speed of "renewal" of albumins by means of radiomethionine can reveal very subtle biochemical changes in nutrition of the secretory processes, and also the nature of the influence on them of various factors. The method may be employed with advantage in investigation of the problem of depletion and restoration of physiological functions.

Tartus State University

STUDY OF THE PHYSIOLOGICAL REGENERATION OF EPITHELIAL TISSUES BY THE METHOD OF AUTORADIOGRAPHY

L. N. Zhinkin

1. The epithelium of the tongue and small intestine in rats and rabbits was investigated. The animals were injected subcutaneously with P^{32} - and S^{35} -labeled methionine.

The investigation was conducted by the method of autoradiography on liquid emulsion of the type "R" (Scientific Research Institute for Motion Pictures and Photography).

2. There was variation in the rate of incorporation of S^{35} in the various layers of the epithelium of the tongue in animals sacrificed two hours after administration of radiomethionine. Most of it was incorporated in the cells of the spinous layer, less by the basal, even less by the squamous layer, and the dead keratinized cells did not incorporate any at all.

3. In animals sacrificed 12, 24 and 48 hours after administration of radiomethionine, cell transfer with incorporated S^{35} from the squamous to the keratinized layer was observed. The whole of the keratin layer became permeated with the radioactive sulfur in 2-3 days. Consequently, renewal of the keratin layer in the epithelium of the tongue occurred in this time span.

4. Most of the P^{32} was incorporated in the basal layer of cells and its amount gradually declined in proportion to the degree of cell differentiation. This character of distribution of P^{32} was maintained independent of the length of the period following introduction of P^{32} in the animal.

5. In the intestinal epithelium both P^{32} and S^{35} were uniformly distributed in all cells. Incorporation is related to the accumulation of enzymes in the cells and to the fact that they remain alive until they are cast into the intestinal lumen in the form of mucus.

Institute of Experimental Medicine

STUDY OF THE ALBUMINS OF A NEW BLOOD SUBSTITUTE - PARENTERIN - IN THE ANIMAL ORGANISM

N. G. Belenky, N. N. Krylova and I. L. Chertkov

1. In order to label the albumins of Parenterin, ^{131}I and methionine labeled by S^{35} were employed. Incorporation of radiomethionine in the blood albumins from which Parenterin was prepared was carried out in vitro and in vivo. In the first case, methionine was added to sterile cattle blood serum and incubated at room temperature, after which the serum was dialyzed and Parenterin prepared.

Marking of the serum albumins was effected by introduction of methionine in the animal donors (rabbits and bull). The animals were killed by bleeding and Parenterin was prepared from the labeled plasma obtained.

2. Labeling of Parenterin albumins by radioiodine proved to be of little use since ^{131}I , not firmly bound to the denatured albumins, quickly split off from them in the blood stream and appeared in the urine. In experiments on dogs and rabbits, within only 6 hours of introduction of Parenterin in the blood only 10-20% of the activity introduced remained; in 24 hours in both species of animals the blood did not contain radioiodine. In a 24-hour urine specimen more than half the entire activity introduced was found and no albumin was detected in the urine.

3. The better method of obtaining labeled Parenterin proved to be the method of incorporation of radiomethionine in the albumins of animal donors. In these conditions Parenterin was obtained with an albumin content, the radioactivity of which corresponded to 650-900 imp/min per 10 mg.

Study of this Parenterin was made in experiments on rabbits and dogs with intravenous administration at a dose of 25-50 mg/kg body weight.

4. The circulation of Parenterin albumins in the organism of the experimental animals was of adequate duration. Six hours after introduction in the blood of rabbits about 40% of the original activity was evidenced, in dogs about 25%. In 24 hours in the blood stream of both species of animals about 10-15% of the introduced albumins remained.

In acute hemorrhage (experiments on rabbits) administration of Parenterin as a substitute for blood loss caused a steady rise in blood pressure and circulation of Parenterin albumin in the animal organism was witnessed in hemorrhagic shock (in experiments with labeled Parenterin) in the same way as in normal animals.

5. Twenty-four hours after administration of Parenterin the animals were killed and the radioactivity of the albumins in various organs and tissues was studied (liver, kidneys, spleen, lungs, brain, muscle, suprarenals, small and large intestine, etc.). The greatest specific radioactivity was found in albumins of the organs actively engaged in the metabolic process (liver, spleen, suprarenal, kidneys).

These results show that the Parenterin albumins are well assimilated in animals with parenteral administration, forming part of the albumins in the organs and tissues.

6. Incorporation of radiomethionine in albumins of native serum in vitro did not give positive results. In sterile conditions, the incorporation of radiomethionine was very weak. High radioactivity of serum albumins was found when the serum was extracted in septic conditions. However, sterile Parenterin obtained from such serum proved to be toxic, due to the presence of mixed microfloral toxins. Intravenous injection of this Parenterin produced in rabbits severe symptoms of poisoning by bacterial toxins. In conditions of toxic shock, the fate of the Parenterin albumins differed from that in normal animals. In the blood albumins, 6 hours after introduction radioactivity was not found. The albumins quickly disappeared from the bloodstream and were concentrated in the organs. The highest specific activity was found in lung albumins (about 20 times higher) and the cardiac albumins (3-5 times more) than in the intact animals. In the brain and muscle albumins, radioactivity was not discovered.

All-Union Scientific Research Institute of the
Meat Industry

ANALYSIS OF THE MECHANISM OF ANTIBODY FORMATION

A. E. Gurvich

1. Antibody formation occurs a short while before the antibodies appear in the blood stream. In the latent period, apparently there is no formation either of antibodies in appreciable amount nor of any albumin or polypeptide precursor of the antibodies. This is indicated by the low content of C^{14} in the antibodies on administration of C^{14} -labeled glycine in the latent period, and by the presence of a correlation between the rate of increase in antibody content in the blood stream and the rate of incorporation of C^{14} in the antibodies.

2. Study of the intensity of inclusion of C^{14} -labeled glycine in antibodies in vitro in sections of various organs and its incorporation in the antibodies of nonspecific γ -globulins in vitro, after removal of the gastrointestinal tract and functional exclusion of the liver, confirmed the theory on the absence of direct participation of the liver and gastrointestinal tract in antibody formation.

3. Simultaneous study of the change in antibody content by means of the immunochemical method and study of the distribution of labeled antibodies enables one to plot a curve of change in the rate of the new daily formation of antibodies. On repeated immunization, intensive reformation of antibodies continues for about two days. Then a sharp inhibition of this process occurs, and in several days the rate of new formation of antibodies drops to 3-5% of the maximal. This process is of a specific character since, in the period of greatly weakened development of one antibody, there may be intensive new formation of another.

4. With repeated immunization by two antigens in several cases a simultaneous and exceptionally intensive increase in the content of the two antibodies and intensive incorporation of C^{14} in both antibodies was observed. Incorporation of C^{14} in each of the antibodies depends on the rate of new formation of each antibody, but not on its immunological properties.

Intensive new formation of one or simultaneously of two antibodies does not inhibit incorporation of C^{14} glycine in the nonspecific γ -globulins.

Institute of Biological and Medical
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Medical Sciences

NEW DATA ON ALBUMIN METABOLISM OBTAINED BY THE ISOTOPIC TRACER METHOD

A. S. Konikova

By means of the method of isotopic tracers a study was made of the influence of chilling, as a factor in reducing vital activity, on the process of albumin formation in an isolated tissue and whole organism.

In the work, use was made of the amino acid methionine labeled by sulfur (S^{35}). The degree of its incorporation in the albumin of the blood vessels of a dog was judged by the intensity of the albumin formation process. Albumin formation was observed in transplanted parts of the vessels previously subjected to freezing at a temperature of -196° , and drying in vacuo. As can be seen from the experimental material, this process of albumin formation occurred at all investigated periods following grafting (from two to seven months). It was further established that in those cases where the grafted sections of the blood vessels were permeable, in absence of side effects and thrombi, the intensity of albumin synthesis in the transplants practically coincided with the intensity of albumin synthesis in an analogous vessel of the recipient.

The findings show that albumin formation is a stable process resistant to low temperatures and drying.

Alongside the experiments described, a study was made of the influence of cooling on the process of albumin formation by investigation of this phenomenon in animals in a state of hypothermia.*

It was seen that in hypothermia, induced by a combination of administration of chemical compounds and chilling of the animal organism by ice to $24^\circ C$, a considerable reduction in the intensity of albumin synthesis occurred in almost all the investigated organs: in the skeletal muscles, various parts of the central nervous system, lungs, serum, sex glands, suprarenals, kidneys and spleen. There was practically no fall in albumin synthesis in the liver, and a very insignificant decrease of this process in the cardiac muscle.

Proof that the changes in intensity of albumin synthesis in hypothermia are specific, and not caused merely by the changed state of the central nervous system under the influence of the soporific substances, is provided by investigations on rabbits** which showed that in the state of drug-induced sleep, intensification of albumin

synthesis from amino acids occurs in the majority of the organs.

The data obtained on incorporation of labeled amino acid in albumins in hypothermia gives grounds for considering that the intensity of the process of albumin formation in the various organs and tissues depends not only on the state of the vital activity of the organism as a whole, but on the state of the individual organs.

Thus, by the method of isotopic tracers, we succeeded in indicating the variable quantitative nature of the process of albumin formation on chilling, and also the close link between the change in this process and the vital activity of the biological subjects.

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USE OF RADIOACTIVE ISOTOPES IN STUDY AND MECHANISM OF EPILEPTIFORM FITS

K. I. Pogodaev

1. Epilepsy is a serious disease both from the practical and theoretical point of view. The most fundamental factor in the picture of this disease is the convulsive fit. It has, however, not been studied adequately. Particularly contentious is the question of the substratum of the basic phase of the convulsive fit—clonic convulsions—and the participation of the cerebral cortex in this process. On the question of the substratum of clonic convulsions, there are, as is known, two opinions, one which supports cortical, and the other, subcortical localization of the clonic phase of the epileptiform convulsive fit.

2. To solve the question as to which sections of the brain are responsible for the clonic phase of excitation, the author used methods of investigation now available in modern functional brain biochemistry, in order to characterize the basic nerve processes—excitation and inhibition. Particularly productive in this field is the method of radioactive tracers.

3. With use of the method of radioactive isotopes, S^{35} (radiomethionine) and P^{32} (phosphate ion), an investigation was made of distribution of these substances and the intensity of albumin and phosphorus metabolism in the cortex, subcortex, cerebellum and the trunk section of the brain of rabbits and rats killed during the clonic phase of the epileptiform electroconvulsive fit. For comparison purposes, analogous investigations in normal animals and in animals killed during the postconvulsion comatous state are reported on. It can be concluded from the data obtained, that during the clonic phase of the fit in all the investigated sections of the brain incorporation of methionine and the phosphate ion is accelerated, and phosphorus metabolism and resynthesis of brain tissue albumins is intensified. During the postconvulsion comatous state, which is characterized by protective inhibition, the speed of these processes falls, quickly reaching normal, or even falling below it.

4. The increased resynthesis of brain tissue albumins during clonic convulsions is combined with increased albumin decomposition (proteolysis) and accumulation of ammonia, which suggests a predominance of the excitatory process in all the investigated sections of the brain (cortex, subcortex, trunk and cerebellum), and consequently their participation in the physiological mechanism of formation of the clonic phase of epileptiform electroconvulsive fits.

Thus, the material from these investigations points to participation of the brain as a whole, and not of a given isolated section, for example the cortex or the trunk section of the brain, in the clonic phase, as postulated by many investigators.

Institute of Higher Nervous Activity of the USSR
Academy of Sciences

DYNAMIC ASPECTS OF DISTRIBUTION OF RADIOACTIVE PHOSPHORUS IN BLOOD, BILE, EXCREMENTS, AND ENDOCRINE GLANDS IN NORMAL RABBIT WITH USE OF CAFFEINE AND BROMINE

A. I. Karaev and A. A. Khudazarov

In the present work, a study was made of the dynamic aspects of distribution of radioactive phosphorus introduced into the rabbit organism in the blood, bile, excrements, and various endocrine glands. In these experiments the investigations were performed in three series— in normal animals and in animals following administration of caffeine or bromine.

The radioactive phosphorus ($\text{Na}_2\text{H}^{32}\text{PO}_4$) was injected subcutaneously in normal rabbits at the rate of $45 \mu\text{c}$ per 1 kg animal weight in the first series, and in the second and third series either 20 minutes after subcutaneous injection of 1 ml 10% caffeine sodium benzoate or after intake of 1 ml sodium bromide solution per 1 g body weight.

As the intensity of the effect of caffeine and bromine changes with passage of time, phosphorus metabolism was studied at various times after administration of radioactive phosphorus, i. e., within three and 24 hours.

The following conclusions may be drawn from the data obtained:

1. Radioactive phosphorus introduced in the organism is eliminated basically by the kidneys (urine) and also by the liver (bile) and intestines (feces).
2. The magnitude of radioactivity in the urine, feces and bile depends on concentration of radioactive phosphorus in the blood.
3. The largest amount of radioactive phosphorus was excreted from the organism in the first three hours, after which elimination of radioactive phosphorus slowed down.
4. Prior administration of caffeine and bromine changed both absorption of the subcutaneously introduced radioactive phosphorus and the process of its elimination through the excretory organs.
5. In normal rabbits the different glands of the endocrine system varied in capacity to absorb the radioactive phosphorus administered.
6. The content of radioactive phosphorus in the various endocrine glands changed with time lapse after administration.
7. Prior administration of caffeine and bromine changed the dynamic aspects of distribution of radioactive phosphorus in the endocrine glands.
8. Absorption and the dynamics of distribution and elimination of radioactive phosphorus introduced into the organism depend on the functional state of the central nervous system.

Physiology Section of the Academy of Sciences, Azerbaijan SSR

RENEWAL OF PHOSPHORUS IN TISSUES WITH EXPERIMENTAL TUBERCULOSIS AND TREATMENT WITH STREPTOMYCIN AND PHTHIVAZIDE

Kh. K. Norman

The object of the investigation was to find whether in experimental tuberculosis there is a change in phosphorus renewal in various tissues, and the effect exerted by streptomycin and Phthivazide therapy.

The specific activity of phosphorus in the tissues, on subcutaneous injection of $\text{Na}_2\text{H}^{32}\text{PO}_4$, served as an indication of phosphorus renewal in the tissues. We investigated the blood, lungs, liver, kidneys, spleen, lymphatic nodes, diaphysis of the femur, and also the white and grey matter of the large cerebral hemispheres. The experiments were performed on 154 adult guinea pigs.

In order to detect changes in the tuberculous animals, the specific activity of phosphorus in the tissues was determined 1, 3 and 7 days after introduction of radioactivity. Changes were found in specific activity of the phosphorus in the tuberculous animals in all the investigated tissues. They were most marked seven days after introduction of P^{32} . The greatest changes were seen in the bone tissue, where the specific activity of phosphorus 1, 3 and 7 days after introduction of P^{32} was considerably less than in the healthy animals. In the large cerebral hemispheres, the specific activity of phosphorus seven days after introduction of P^{32} was much higher than in healthy animals.

With effective streptomycin and Phthivazide therapy of the guinea pigs suffering from tuberculosis, normalization of specific activity in all the investigated tissues, with the exception of bone tissue, was observed. The greatest effect being seen with use of streptomycin.

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CERTAIN ASPECTS OF DOSIMETRY IN BIOLOGICAL EXPERIMENTS

E. A. Liberman

The report outlines views on the system of dosimetric conceptions from the standpoint of experimental biology. Existing methods of dosimetry are considered from the point of view of the requirements of biological experiments (measurable values and their relation to the characteristics of interaction between radiation and matter). From this point of view sources of radiations and methods of irradiation are considered.

Institute of Biophysics, USSR Academy of Sciences

V. APPLICATION OF ISOTOPES AND RADIATIONS IN ANIMAL REARING AND FISHERY INDUSTRY

USE OF γ -RADIATION IN LENGTHENING STORAGE TIME OF POTATOES

L. V. Metlitsky, B. A. Rubin and V. G. Khrushchov

On the basis of a number of investigations it has been discovered that γ -irradiation of potatoes exerts a powerful retardation effect on sprouting of tubers, making it possible to preserve the potato for one year and more. However, until recently it had not been possible to devise a really efficacious method of irradiation of large quantities of potatoes, due in a large measure to the fact that the physicochemical processes in irradiated tubers had received little study.

The present investigations showed that retardation of sprouting of tubers induced by γ -rays results from the joint influence of a number of factors: change in state of cellular colloids, alkalinization of cellular sap in the meristematic tissues, suppression of nucleic acid synthesis and of the activity of oxidative enzymes (primarily in the structures of the protoplasmic elements), slowing down of gas exchange of respiratory tissues.

These metabolic changes lead to a certain lowering of resistance to microorganisms in the tubers. In order to avoid this it is necessary to irradiate the potatoes with stringently regulated minimal doses.

Dosage depends largely on the method of irradiation employed. The magnitude of the dose may be decreased by increasing the intensity of radiation. One-time radiation has a more powerful retardatory action on sprouting of tubers than does the same amount of radiation in divided doses.

In selecting the dose the potato variety and physiological state of the tubers should be taken into account. While for the Lorkh variety a dose of 10,000 r is necessary, for many other varieties it may be reduced to 8,000 r. In irradiating the potato the dose in the fall should be higher than on irradiation at the end of winter.

In experiments with the Lorkh variety irradiated with Co^{60} in the fall at a dose of 10,000 r and radiation intensity of 600 r/min this variety kept well on storage in cellars for one year. Total loss and wastage was 10%.

As a result of these investigations a method was worked out for irradiation of potatoes which we recommend for trial on an industrial scale: the method is based on a combination of a stationary source of radiation with a moving supply of the potatoes for irradiation. The entire irradiation process is carried out in a single, continuous operation.

The irradiation method recommended ensures a high degree of efficiency of radiation, storage of irradiated potatoes without the presence of a radiation source in storehouses of current construction, and reliable protection for the personnel against radioactivity.

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APPLICATION OF RADIOACTIVE ISOTOPES IN FOOD PRESERVATION

N. D. Chernaev

Modern means of preserving food products are based on heat sterilization. Food may, as a result of such treatment, be denatured to a considerable extent. In order to avoid such undesirable features in the preservation of food stuffs, workers in the food industry are seeking for new ways of sterilizing products, without the inherent defects of heat methods.

Such a new method, in principle, is the method of sterilizing products based on use of ionizing radiations. With this method microorganisms can be suppressed without any appreciable increase in the temperature of the products, i.e., cold sterilization occurs. Roentgen, cathode and γ -rays are most suitable for this purpose.

Various types of electron accelerators served as the source of the first two types of rays. The third type of ray was produced by radioactive isotopes.

Radioactive elements artificially produced or obtained from reactor wastes are of the greatest practical importance.

These radioactive elements which are in good supply at an economical price are of special value in industry. This category includes the radioactive wastes of nuclear reactors - fission products of U^{235} .

These fission products, such as γ -emitters, may be used in various ways depending upon their state and the stage of decay at which they are obtained. Thus, for example, they may be contained in the fuel element at the periphery of cooled-down homogeneous reactors, in burned-up fuel rods and in the wastes, by chemical separation of uranium and plutonium from the treated fuel.

The constructions of various projected or existing types of γ -emitters in the USSR and abroad for use in the preservation of foodstuffs are described in the report; types of radiation treatment of foodstuffs are enumerated, applicable in a number of technological processes; the influence of radiation doses on the quality of foodstuffs and enzyme inactivation are discussed; the question of the risks to the consumer of irradiated products is considered.

The report ends with brief information on the further development of research in this field.

All-Union Scientific Research Institute of the
Conserve and Vegetable Processing Industry

ORGANOLEPTIC AND PHYSICO-CHEMICAL CHANGES IN FOODSTUFFS PRESERVED BY γ -RAYS

B. N. Zelenin and G. L. Pavlova

The purpose of the investigation was to study the changes in foodstuffs preserved by γ -radiation in relation to dose, and also to clarify the length of storage time of the tested samples.

The products subjected to γ -radiation sterilization were prepared by the usual means and stored in hermetically sealed standard glass or in tin containers.

Radiation was conducted within the cavity of a cobalt cylindrical γ -radiator. The working dose was of the order of 630 rep/min. The control samples were sterilized in an autoclave. Organoleptic evaluation and analysis of the samples was made both following irradiation and throughout storage. Some of the samples were

subjected following irradiation to incubation and microbiological control; the bulk of samples, however, were kept under observation - storage times were determined at room temperature.

The following was established.

1. The character and degree of change in the physicochemical and organoleptic properties of the food-stuffs with γ -irradiation depend on dosage, the properties of the products themselves, and on pre-radiation treatment.

2. Doses of an order of 2,000,000 rep in most cases ensure sterility of preserved foods. These doses, however, lead to undesirable changes in the organoleptic properties of the food products. Doses of 1,000,000 to 1,500,000 rep do not ensure sterility; storage time is reduced to 3-4 months. Changes in the physicochemical and organoleptic properties are insignificant. Doses of 300,000 to 500,000 rep limit storage time to 1-3 weeks, but have almost no effect on the natural properties of the food.

3. Foodstuffs such as beef, fish, green peas, apple juice and carrot puree lend themselves best to cold sterilization methods.

4. Less promising are prepared cauliflower, potatoes and carrots soaked in brine. More fundamental changes occur in the organoleptic qualities of these products.

5. In plant oils, doses of 2,000,000 rep produce very slight physicochemical changes. However, organoleptic changes are already apparent at doses of 1,000,000 rep. In using irradiated oil for roasting these changes disappear. Doses of 11,000,000 rep produce changes in the physicochemical constants of the oils; the acid number shows a slight increase, the iodine number and color index decrease, specific gravity and viscosity increase. The character of these changes makes it reasonable to postulate development of polymerization. The observed deodorization and clarification open up new prospects for the use of ionizing radiation in processing of fats and oils.

All-Union Scientific Research Institute of the
Conserve and Vegetable Processing Industry

IONIZING RADIATIONS AS A MEANS OF CONTROLLING INSECT PESTS IN GRAIN STOCKS

A. A. Peredel'sky, P. D. Rumantsev, L. Z. Rodionova,
A. V. Biber'gal and E. S. Pertsovsky

1. Present day science and techniques lead to methods of combating grain insect pests in granaries through the medium of ionizing radiations.

2. The literature on the action of ionizing radiations on insects - experiments with grain weevils - with suitable calculations show that technically, economically and biologically it is advisable, in destruction of pest populations, to use only comparatively small doses (10,000 r) of Roentgen or γ -rays, which produce general infertility or fatal damage in the embryonic or post embryonic development of the progeny of the irradiated parents.

3. Furthermore, on irradiation at the given dose extinction of weevils in all stages of development is accelerated.

4. On irradiation the average food consumption of the dying weevil population perceptibly falls, which favors use of the method of ionizing radiations in combating grain stock pests.

5. To assist dosage calculation, blue prints of a powerful γ -radiation installation suitable for pilot-plant testing of irradiation of consumer grain supplies are being drawn up.

6. Radioactive isotopes of cobalt and cesium and mixtures of nuclear reactor wastes are proposed as sources of radiations.

Institute of Biophysics of the USSR
Academy of Sciences, and the
All-Union Scientific Grain Research Institute

KILLING AND PRESERVATION OF THE MULBERRY SILKWORM COCOONS BY γ -RADIATION

T. V. Tsetskhladse, V. A. Barnov, V. E. Chikovani,
T. N. Cheidze and L. M. Thelidze

1. The technique of preliminary treatment of cocoons is of fundamental importance for the quality of silk thread. The methods now applied of killing of the chrysalis and drying of the cocoons are labor-consuming and to a certain extent deform the membrane of the cocoons, produce a denatured sericin, impair unraveling capacity, reduce the dynamometric properties of the cocoon thread and the yield of raw silk.

2. Investigation of killing the mulberry silkworm chrysalis by γ -radiation showed it to be a promising process.

3. The average lethal dose for the spring fattened chrysalis was 200,000 rep, for the summer one 150,000 rep, and for the autumn one 100,000 rep. In a chrysalis receiving 30-40% of the lethal dose within the first days of radiation and later doses of 1,000 rep the stage of metamorphosis was protracted for 10-12 days.

4. The value of the lethal dose depends on the age of the chrysalis; for a one day old chrysalis, 10 to 12,000 rep; for five day old ones, 50,000 rep; and from the eighth day, 100-200,000 rep.

5. Tagging of the irradiated parts showed that the dynamometric properties of the silk thread are improved as compared with box-dried cocoons. The raw silk yield was considerably increased. The irradiated cocoons were well preserved under usual storage conditions.

Institute of Physics of the Academy of Sciences of the
Georgian SSR, and Central Textile Laboratory,
Textile Industry Ministry, Georgian SSR.

CHANGE IN CHEMICAL COMPOSITION AND ORGANOLEPTIC PROPERTIES OF γ -IRRADIATED WINE

G. I. Beridze and M. V. Kurdgelashvili

1. Changes in the physical and organoleptic compositions of γ -irradiated wine were studied. Co⁶⁰ was used as the source of radiation. The experiments were performed on samples of European and Kakheti types

of table wines and various desert wines with high and low content of alcohol, acid, tannin and extractive matter. The experimental wines were exposed to varying radiation doses.

2. γ -irradiation of wine led to chemical changes and to alteration in taste of the treated product. The higher the dose of γ -rays the more powerful the radiation influence on the chemical and organoleptic properties of the wine.

3. The influence of large γ -radiation doses (10,000-50,000 r) on wine produced disturbance in the chemical composition and blend, and also changes in taste.

4. Application of various doses of γ -rays in different types of wines caused color change, formation of Madeira tint and appearance of a mousy taste, intensified with increase in dosage.

5. Intensification of the mousy taste and odor of the γ -irradiated wine was due to the increased value of the oxidation-reduction potential with increase in dosage of ionizing γ -rays.

6. After 2-3 months irradiation, the characteristic properties of the wine were restored; the wine became lighter, blended, and valuable taste properties developed.

On γ -irradiation of the wine in bottles, by reducing the air space, one can minimize these changes and achieve an improvement in quality of production.

Institute of Horticulture and Viticulture of the
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METHODS OF USE OF IONIZING RADIATION IN THE PRODUCTION OF BACTERIAL PREPARATIONS

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I. M. Goncharenko, A. P. Duplisheva, T. S. Sedova and V. G. Khrushchov

The production of bacterial preparations is a most important branch of the medical industry. The manufactured preparations, in particular prophylactic vaccines, are used on a mass scale. Sterilization is an essential process in the production of any bacterial preparation.

Experimental data were obtained supporting the use of the atomic technique in the production of bacterial preparations.

1. The doses of γ -radiation which have a bactericidal effect on the intestinal typhoid group and on spore-bearing soil bacteria were determined.

2. The special morphological features of bacterial growth and multiplication after irradiation with sub bactericidal doses of x-rays and also the morphological changes in the bacteria killed by x- and γ -rays were identified. The investigations were conducted with the method of microphotography and electron microscopy.

3. The possibility of γ -radiation sterilization of nutritive media was demonstrated. Radiation by γ -rays (1,500,000 r) did not impair the nutritive properties of Gottinger agar for growth of bacteria of the intestinal typhoid group.

4. It is possible to obtain typhoid and dysentery vaccines, killed by γ -irradiation. These "radiovaccines," as was shown in experiments on mice, retain their immunogenic properties; the toxicity of these vaccines for mice did not rise. Antigens prepared from bacteria killed as a result of radiation possess well marked immunogenic properties.

5. γ -irradiated diphtheria and tetanus toxoids (1,500,000 r) maintain their immunological properties.
6. When horse native anti-diphtheria immune sera was irradiated with γ -rays (1,500,000 r) the antitoxin titer fell by 25-30%, the diapherm - 3 by 20%. The viscosity of the irradiated sera increased. Electrophoregrams showed considerable disturbance in the serum globulin fractions.

Thus, the following possibilities of use of the atomic technique in the production of bacterial preparations were demonstrated.

1. Preparation of killed corpuscular and chemical vaccines (antigen complexes) by means of γ -radiation.
2. Cold sterilization of the finished product - vaccines and toxoids.
3. Cold sterilization of nutritive media.
4. Cold sterilization in detoxication of bacterial production wastes.

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ACTION OF IONIZING RADIATION ON THE PROCESSES OF FERTILIZATION AND FISSION IN FISH

A. A. Nelfakh

1. The object of the first part of the work was to clarify the pattern of interaction between two irradiated sex cells. In other words the investigation was concerned with the specific complication arising on transfer of radiation from the haploid sex cell to the diploid zygote. The ripe sex products of the groundling were irradiated at various x-ray doses (from 100 r to 100,000 r). Artificial fertilization was employed to produce zygotes consisting of irradiated gametes with various dose combinations. The criterion of the radiation effect was the survival rate of the embryos.

2. With irradiation of only one gamete (male or female), the embryonic survival rate was reduced as dosage increased, reaching a minimum at 2000-3000 r. Later the survival rate again increased owing to the "deactivation" of the irradiated gamete by means of haploid development on the part of the second, non-irradiated sex cell (Hertwig effect).

3. With irradiation of both gametes it was found that if the radiation dose to which both gametes are exposed is relatively small (up to 2000 r) the percentage mortality of the progeny is the same as with application of the dose to one of the gametes, i.e., in this case no interaction between the two sex cells is found. With larger radiation doses the most destructive effect is obtained when both gametes are irradiated by roughly the same doses. This effect is heightened with an increase in dosage.

4. In order to explain the data obtained a hypothesis was advanced on the various types of damage of the gametes and on the relative independence in the zygote of the irradiation gametes. On the basis of the quantitative findings on the irradiation of one gamete the suggested hypothesis enabled us to make a specific theoretical calculation and to plot theoretical curves irradiation both gametes with any combination of doses. The theoretical curves were in sufficiently close agreement with the experimental ones to substantiate the hypothesis advanced.

5. Change in the radiosensitivity in the process of fertilization and early fission was investigated by means of irradiation of a fertilized spawn at various time intervals after seeding. The experiments showed that the survival rate of the embryo was particularly low when radiation was applied at the end of the first hour after seeding (at a temperature of 13°C for the groundling and 16°C for a type of sturgeon) and approximately at the first second following fissions.

6. Comparison of the times of particular radiosensitivity with times of egg and also with cytological data showed that the most sensitive phase was that of a phase in the nuclear cycle (apparently preparatory to mitosis). Of essential importance is the fact that this phase, corresponding to the first division breakdown, was separated from the division itself by more than one hour and apparently proceeds in the pronucleus before fusion.

7. It may be concluded from the findings obtained in the present work that in the initial period of development the mechanism of action of ionizing radiation is compatible with the concepts held on the genetic nature of the action of radiation on the nucleus. The change in radiosensitivity is of a nonspecific quantitative nature and is determined by change in the structure of the nucleus.

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RESULTS AND PERSPECTIVES WITH USE OF C^{14} IN STUDY OF THE CARBON CYCLE IN IMPOUNDS

Ya. I. Sorokin

1. The processes associated with the carbon cycle are at the basis of the biological productivity of impounds. Many links in the carbon cycle in impounds remain unstudied owing to the difficulty of investigating them by normal chemical methods. These methods are insufficiently sensitive to detect transformations in the multifarious forms of living and dead organic matter. Nor do they allow one to trace the path of the organic matter in the carbon cycle.

2. Solution of the basic problems associated with the carbon cycle in hydrobiology is possible only with use of radioactive carbon. Thanks to the special properties of this isotope (soft radiation, length of half-life period) it is very suitable for such investigations.

3. In the Microbiology Laboratory of the USSR AS Institute of Biology of Reservoirs, as a result of three years work, ways of using C^{14} to solve a number of important problems of carbon exchange in impounds have been worked out.

4. A method was elaborated for determining, with the aid of C^{14} , daily productivity of photosynthesis of the phytoplankton under 1 m^2 surface not requiring the placing of a phial at each point. Application of such a method considerably simplified the work and in 1955 made it possible to determine the annual photosynthetic production of the Ribinski reservoir, all the sections of which show extensive and varied output. The yield equalled 408,000 t of dry organic matter in one whole impound, or 125 g glucose per m^2 area.

5. Determination (with use of C^{14}) of the chemosynthetic production of organic matter showed that this process in the impounds is closely linked with anaerobic decay of organic matter in muddy deposits, which in certain conditions reaches considerable proportions. Since with chemosynthesis there is accumulation of the bacterial mass serving as food source for the water nonvertebrates, this process is a basic trophic factor. It was established that autotrophic bacteria are eaten and assimilated by water nonvertebrates.

6. By means of C^{14} a method of study of algae - bacteria feeding of water nonvertebrates was devised, enabling a qualitative estimation of the assimilation of the food matter. Thus, with this method data were obtained on the feeding of daphnia and tendipedidae larvae by labeled bacteria and algae.

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Academy of Sciences

USE OF ISOTOPES IN STUDY OF THE ROLE OF MICROORGANISMS IN FORMATION OF SHORSU SULFUR DEPOSITS

M. V. Ivanov

1. In study of the role of microorganisms in the turnover of matter in nature, quantitative and qualitative analyses of the microflora of silt, soil or water are normally made. However, such registration of the presence of this or that group of microorganisms reveals nothing about the intensity of the process caused by these microorganisms in natural conditions.

2. The report gives the results of the first experiments to determine, by means of labeled sulfur, the intensity of sulfur turnover in the Shorsu deposits.

3. On addition of labeled sulfate ($\text{Na}_2^{35}\text{SO}_4$) to samples of underground water, labeled hydrogen sulfide appeared only in presence of active desulfurizing bacteria. The daily intensity of formation of hydrogen sulfide reached 0.078 mg/liter H_2S . It can therefore be said that hydrogen sulfide in the underground waters of the Shorsu deposits is of biogenous origin and that the high mineralization of underground waters is not an obstacle to development of desulfurizing bacteria.

In order to clarify the role of the microorganisms in the oxidation of hydrogen sulfide leading to sulfur formation, labeled sulfide (Na_2^{35}S) was used.

4. The experiments showed that in the presence of microflora (*Thiobacteriales* bacteria) oxidation of hydrogen sulfide proceeds with appreciably greater intensity than in experiments with formalin-killed microflora. It was revealed that as a result of oxidation of hydrogen sulfide molecular sulfur is accumulated, the daily production of which reached 60-70 mg/liter.

5. From the data obtained on distribution of desulfurizing and acid bacteria in the Shorsu sulfur deposits and the results of the experiments with isotopes it can be said that the microorganisms take an active part in the formation of the sulfur deposits of the epigenetic type.

6. The experiments conducted with labeled sulfur indicate the great possibilities for use of isotopes for investigating geological activity of microorganisms in natural conditions.

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STUDY OF THE BIOLOGICAL PRODUCTIVITY OF TANKS BY MEANS OF RADIOISOTOPES

V. I. Zhadin, A. G. Rodina and A. S. Troshin

Using P^{32} and Ca^{45} in experimental conditions, a study was made of adsorption of phosphorus by various tank bottoms and consumption of phosphorus and calcium by bacteria, phytoplankton, and by the higher water vegetation (elodea), algae overgrowth and zooplankton.

A periodic investigation was made of the radioactivity of samples from the bottom, bacteria from the bottom and water samples from the bottom by elutriation and from the water layer by filtration through a No. 2 membrane filter - phytoplankton (after removal of the zooplankton by pipette), zooplankton recovered (by pipette), plant tissue of elodea and algae overgrowths. The water samples were used before filtration and

after filtration through the No. 2 membrane filter. The radioactivity of the samples was expressed by the number of impulses per minute per unit weight or volume.

In the absence of plankton and vegetation the largest amount was adsorbed by the peaty bottom (85,000 imp), much less by a rocky bottom (20,300 imp), clay (13,400 imp) and sand (11,000 imp per 1 g dry weight). Adsorption of phosphorus by clay and sandy bottoms was principally effected by their bacterial flora content.

On introduction into the aquarium of a combined mineral fertilizer (N, P, K, Ca) the phosphorus was partially adsorbed by the bottom, but the bulk of it was assimilated by the bacteria and phytoplankton, algae overgrowths and elodea. Following them phosphorus was assimilated in a vast amount of zooplankton. The bacterioplankton showed radioactivity almost equal to that of the phytoplankton (up to 6000 imp per 1 ml of water on the sixth day of the experiment). The algae overgrowths gave at the same time up to 135,000,000 imp and the zooplankton up to 108,000,000 imp per 1 g moist weight. When elodea were present they showed 64,000,000 imp per 1 g moist weight.

Radioactive calcium (Ca^{45}) when introduced with the combined fertilizer was accumulated in considerable amount by the elodea and zooplankton and a small amount was used by the bacteria or phytoplankton or was adsorbed by the bottom. The radioactivity of the elodea on the third day of the experiment reached 426,000 imp per 1 g moist weight and in the algae overgrowths it varied from 100 - 150,000 imp per 1 g moist weight. In the bacteria and phytoplankton 20-60 imp per 1 ml water, in zooplankton 77,000 to 303,000 imp per 1 g moist weight, and in the bottom 100-800 imp per 1 g dried weight.

The result of the experiments and observations on fish-rearing pools justify the use of fertilizers, which give a significant increase in pond fish production. It is advisable to introduce only solutions of mineral fertilizers in the water. The first portions of the fertilizers were introduced in the ponds in early spring (before the development of the higher water vegetation). The higher vegetation growing in the ponds should serve as the organic component of the complex (organomineral) fertilizer. Mineral and organic fertilizers were introduced in the ponds periodically throughout the summer according to the degree of their utilization in biological output.

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TECHNIQUE FOR TAGGING FISH BY RADIOACTIVE CALCIUM

N. P. Rudakov

A number of scientific organizations have in the last few years been engaged in the task of working out methods for tagging fish by radioactive isotopes. However, although a certain amount of factual material has been assembled in this field, the problems of isotope dosages and the efficacy of tagging of fish of various ages have not been sufficiently elucidated.

The object of the investigation was: a) study of the laws governing accumulation of radioactive calcium in the fish organism, and b) study of radioactive calcium uptake by fish of various ages.

The study was carried out on young carp (*Cyprinus carpio* L.), weighing 0.064 g at 16 days old, 0.496 g at 30 days, and 5.0 g at 64 days. The experiments were performed in aquarium conditions. The source of radioactivity was a preparation of calcium chloride ($\text{Ca}^{45}\text{Cl}_2$). The following activities were employed: 3.0 μC , 1.0 μC , 300.0 μC and 30.0 μC per liter. For the purpose of tagging, the fish were placed for one hour in solutions at these concentrations and then investigated for radioactive calcium content in their organism.

Some of the fish placed in solutions with a specific activity of 1.0 μC per liter were used to determine the optimal concentration of radioactive calcium required for the experimental period.

Determination of the radioactive calcium content in the fish was made in ash suspensions. Total calcium was estimated Trilonometrically with use of murexide as indicator.

The Ca^{45} content was determined in the young carp at specific time intervals after tagging (1 min, 1 hour, 3 hours, 12 hours and 24 hours).

The radioactive calcium was rapidly absorbed by the young carp of different size and age. A substantial part of it was absorbed by the organs of the fish, while some of it was washed out in the first 24 hours after tagging.

Absorption of total calcium by the young carp per 1 g ash (with a high calcium content in the medium) does not depend on the concentration of the initial solutions. As the fish grow the absorption of calcium per unit weight decreases 1.5-2.0 times.

The most rapid decrease in the content of radioactive calcium in the fish in solutions of the greatest specific activity was observed in the first 24 hours. Solutions with a specific activity of 1.0 μC per liter may be regarded as the most suitable for the tagging of the young carp.

The radioactivity of the fish after the first 2-3 months of breeding was highest with tagging of the largest young, considerably surpassing the activity of the young of smaller dimensions.

All-Union Scientific Research
Institute of Lake and Stream Fish Breeding

APPLICATION OF P^{32} AND Ca^{45} IN STUDY OF SOME ASPECTS OF PHOSPHORUS AND CALCIUM METABOLISM IN YOUNG CARP AND STURGEON

M. P. Bogoyavlenskaya and I. A. Shekhanova

1. Application of P^{32} and Ca^{45} with use of a specially constructed chamber made it possible to establish the paths of penetration of phosphorus and calcium ions from the water to the body of fish. The bulk infiltrates through the surface of the gills and mucous membrane of the mouth; the least through the integuments of the body surface of the young carp and sturgeon.

2. The phosphorus and calcium ions penetrating from the water are distributed in the very first hour in all organs and tissues of the fish body. The largest amounts of phosphorus and calcium were determined at the site of penetration (in the gills, mucous membrane of the mouth, intestine and in the skin). The maximum amounts of calcium, unlike phosphorus, were found in the integumentary bones (operculum in the lepidoptera). In the axial skeleton a smaller concentration of calcium was found.

3. The results of analysis showed that phosphorus ions penetrating from the water are essentially accumulated in the body of fish in the form of organic phosphorus compounds.

4. With passage of time a redistribution of phosphorus and calcium ions in the fish was observed.

5. In 1-2 days the radioactive calcium was essentially localized in the bone elements. Although phosphorus was redistributed in the fish organism, its total activity in the soft tissues and bone elements did not change.

6. With use of radioactive isotope labelling it was necessary to take into account that this was not a mechanical process, but an intrinsic part of the metabolic activity of the investigated fish. It was specially important in this respect to pay particular attention to the fish requirement of the substance used as tracer and not to unduly exceed the normal content of the substance in the water.

All-Union Scientific Research Institute of
Sea Fish Economy and Oceanography

STUDY OF CALCIUM METABOLISM IN HENS BY MEANS OF RADIOACTIVE CALCIUM

V. K. Bauman

The essential object of the investigations was to study the mechanism of calcification of the hen egg--shell. With use of differing amounts of calcium in the ration, and on the basis of different yields in the laying hens, phosphorus, calcium, and also the radioactive calcium balance were studied.

The method of the experiment was essentially based on the fact that there is selective absorption of radioactive calcium by bone tissue.

On parenteral administration of Ca^{45} in hens the skeletal calcium was tagged, while the calcium taken by mouth did not contain radioactive isotopes. This made it possible to trace, in shell formation, participation of calcium derived from the two chief sources -- skeleton and digestive tract.

Support for the hypothesis that the skeleton is the sole source of calcium in shell formation was found in the fact that in all eggs laid 24 hours after administration of Ca^{45} , significant activity (about 40% of the dose) independent of the amount of calcium in the ration, was observed in the shells. The uniform activity observed in the eggshells may be explained by the fact that in their formation calcium is derived from the skeleton in approximately equivalent amounts.

The entire calcium in the food, before being deposited in the shell, enters the skeletal calcium depot, from whence its utilization is strictly regulated by the relevant neuroendocrinal mechanism.

In study of skeletal calcium metabolism, convincing proof of its exceptionally high activity in laying birds was obtained. The speed of disappearance of radioactive calcium from the skeleton is in close relationship to productivity. In hens laying more than 25 eggs in 2 months only traces of Ca^{45} were found in the skeleton, while in the skeletons of hens which did not lay a single egg in this period, more than half the dose of radioactive calcium introduced persisted.

The most active metabolism was shown in the porous bone substance filling the bone cavity in hens. The speed of metabolism in this substance was 4-5 times greater than in compact tissue.

The degree to which the various bones of the skeleton participate in shell formation is connected in large measure with their capacity to accumulate active porous matter in the cavities. During egg laying, the breast and pelvic bones and ribs show particularly marked change.

The existence in bone tissue of various forms of calcium, with different metabolic speeds, may be postulated on the experimental findings.

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COMPARATIVE STUDY OF COBALT BALANCE IN THE ORGANISM BY MEANS OF Co^{59} AND Co^{60}

V. V. Kovalskiy, A. D. Gololobov, A. A. Chernova

Experiments concerned with cobalt balance in sheep showed that assimilation of Co^{59} (cobalt chloride contained in fodder) reaches on average 82%. In another series of experiments in sheep, assimilation of Co^{59} reached 70%, in rabbits about 77%, in pigs 75%. In experiments performed on cattle with use of Co^{60} this high assimilation of cobalt was not observed, being only 10-20%. In experiments on rats even lower assimilation of Co^{60} in the 5-7% range was obtained.

Such discrepancies in Co^{59} and Co^{60} balance, reported by various authors with use of different animals, cannot be considered merely fortuitous. Accordingly, it was necessary to perform a comparative study of Co^{59} and Co^{60} balance in animals. For this purpose experiments were carried out with a single administration of Co^{59} and Co^{60} in the rabbit organism, a method which ensures that the balances are completely comparable, and excludes possible interference of experimental factors, which may arise even in different animals of the same species. Estimation of both Co^{59} and Co^{60} excreted from the organism was performed on the same samples of feces and urine. Co^{59} was determined chemically by the colorimetric method with nitroso-R-salt. Co^{60} was determined according to number of impulses; the impulses were converted into specific radioactivity on the standard solution.

Investigations of cobalt (Co^{59}) balance in rabbits showed that there was 87-90% assimilation of the 600 μCi cobalt (approximately) administered in green fodder in a seven-day period. Each of the rabbits was given 35 μCi of the radioactive isotope Co^{59} . At the same time, a load of mineral cobalt carrier (Co^{59}) — 1500 γ was given. The total seven-day ration for each rabbit contained 2100 γ of Co^{59} in the food and as mineral salt supplement. Its assimilation, expressed in percentages of the cobalt introduced in the organism, varied from 68 to 77%, i.e. was somewhat less than assimilation of the food cobalt by rabbits not receiving Co^{60} . Assimilation in these same rabbits of Co^{60} was significantly less. In the seven days of the balance testing period 1.5 to 14.72 μCi Co^{60} still remained in the organism, amounting to 5-42% of the amount of cobalt introduced.

The rate of excretion of Co^{59} and Co^{60} during the days of the balance test period furnish interesting information. Maximum excretion of Co^{60} occurred in three days, that of Co^{59} in four days. These differences are not open to doubt and were repeated in all the experimental animals.

The differences in Co^{59} and Co^{60} balances were due to the characteristics of metabolism of the small trace amounts of labeled cobalt and the physiological amounts of Co^{59} , and also to the unavoidable differences in the methods of investigating them.

On the basis of previous investigations one might have expected that the trace amounts of radiocobalt would be deposited and retained in the organism to a lesser degree than was the physiological amount of Co^{59} . In determination of the radioactive isotope it was necessary to consider that part of the introduced substance in the excretions of the organism; in determination of the normal chemical element it was necessary to take account not only of part of the introduced substance, but of a significant amount of the same element which was derived from the tissue depots, and not amenable to determination.

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Sciences

USE OF SULFUR IN SYNTHESIS OF HAIR KERATIN

A. L. Palucheva

The special features of utilization of sulfur in synthesis of hair keratin in ruminants (fine- and coarse-wool sheep and the saiga antelope), in rodents (rabbits) and in carnivores (dogs) were studied. Tests were made with inorganic sulfur compounds ($\text{Na}_2\text{S}^{35}\text{O}_4$, Na_2S^{35}) and organic compounds (methionine, cystine and thiocarbamide) introduced by mouth in single or double doses 0.5-2.0 mc). Altogether 52 animals were used.

Use of inorganic sulfur for hair growth in various animals was distinguished by features which deviate from the accepted classification system based on types of feeding and digestion. A clear relationship between type of hair coat, hair sulfur content and rate of deposit of sulfur in hair was not found. Fine-wool sheep with well developed wool covering and coarse-wool sheep yielding 2-4 times less wool, and also carnivores (dogs) were capable of using inorganic sulfur in the synthesis of cystine for hair keratin. Inorganic sulfur compounds are not used in hair growth in saiga antelope, which are related to sheep, and covered by short hair with a low sulfur content, nor by rabbits which accumulate a large amount of sulfur in the hair.

In various animals in the period of moulting sulfur utilization capacity varied. In saigas and rabbits, the processes of keratin synthesis with use only of organic sulfur are intensive in the young newly forming hairs and carry on in old hair still subject to change. In coarse-wool sheep, both organic and inorganic sulfur are used in growing hair (wool). However before moulting large clumps of hair still firmly attached to the skin are completely excluded from the sulfur metabolism. Nor was the labeled sulfur found in all hairs in the moulting period in dogs.

In bacteria-free newborn lambs and saigas hair keratin synthesis from inorganic sulfur compounds does not occur; this is at variance with the conception that in newborn organisms synthetic ability is in general higher than in adult animals, and indicates the deficiencies in the relevant albumin and sulfur metabolism enzymes, and also the importance of intestinal microflora in this process.

Deposition of sulfur as hair growth proceeds occurs unequally, being dependant on its concentration in the organism. Autoradiographic investigations of hair on an x-ray film and with use of nuclear emulsion show that deposit of sulfur in hair decreases steeply in line with the rapid and sharp fall in the blood sulfur concentration after a single administration of S^{35} . There is a perceptible repeat trace of sulfur in growing hair following repeated administration of sulfur at several time intervals which makes it possible to utilize radioactive sulfur in determination of the rate of hair growth.

Hypo- and hyperthyroidism, while influencing the rate of hair growth, does not fundamentally interfere with inorganic sulfur utilization in hair keratin synthesis.

All-Union Scientific Research Institute of Animal
Breeding

USE OF LABELED IODINE IN DETERMINING FUNCTIONAL STATE OF THYROID GLANDS IN SHEEP

E. A. Nesterova

Enzootic disturbances in metabolism in farm animals due to iodine deficiency, encountered in Siberia, the Far East, Byelorussia and in other places, have not been studied to any extent. Iodine deficiency in the fodder reduces reproductive capacity and animal productivity, and retards development of the young. In regions with endemic goiter, table salt enriched with iodine is added to the animal rations. In places where iodine deficiency is weakly expressed and the animals are not goitrous, practical measures to improve iodine provision for the animals are not taken.

For the purpose of diagnosing iodine deficiency in sheep in cases where it is not accompanied by development of goiter, the method of labeled atoms, — widely applied in various countries for diagnosis of hypo- and hyperthyroidism in humans — was employed. The functional activity of the thyroid gland was judged by the rate of absorption of trace amounts of labeled iodine. In the diagnosis of enzootic hypofunction of the thyroid gland discovery of the laws governing the normal changes of its functional state is of basic importance. This work was aimed at establishing these laws.

Inspection of the functional activity of the thyroid gland in sheep was performed under the conditions of the physiological studies of the All-Union Institute of Animal Breeding, and in individual collective farms of the Mari SSR where goiter was found among the population. At the same time a study was made of iodine content of fodder and drinking water.

The seasonal features of labeled iodine accumulation in the thyroid gland of sheep, connected with varied physiological state of the animals (pregnancy, lactation, etc.) were established. With use of labeled iodine in lactating animals it is necessary to make a simultaneous study of radiiodine accumulation in the thyroid glands of the suckling lambs. The correlation of labeled iodine in the thyroid glands of the mothers and suckling lambs changed as lactation proceeded. At the beginning of lactation the mothers show increased iodine demand. The reduced secretion into the blood of the thyroid gland hormone in sheep in the summer may be accompanied by intense absorption of labeled iodine, which makes it impossible to draw conclusions on the functional state of the gland on the basis of only short experiments (about two days). The duration of investigation of sheep thyroid gland must not be less than five-six days in order to achieve maximum absorption.

All-Union Scientific-Research Institute of Animal Breeding.

INFLUENCE OF RADIOACTIVE PHOSPHORUS ON WEIGHT AND ENERGY PROCESSES IN RUMINANTS

E. M. Berkovitch

1. The influence of ionizing radiations on metabolic and energy processes have not been studied at all adequately, and the data presented by various authors who have studied this question are of a conflicting nature. This may be due to the peculiarities in metabolism of animals of different species.

2. As metabolism in ruminants differs markedly from that in monogastric animals, study of the reactions of ruminants to ionizing radiations, are of great theoretical and practical interest.

3. After administering radioactive phosphorus at a dose of 16-180 μ c per 1 kg live weight in goats and sheep, a gain in weight in 6-15 days was observed, amounting to as much as 2-3 kg. Later the weight fell to the initial level and, occasionally, by the 25-30th day following administration of radioactive phosphorus, the weight of the animals was less than the initial weight.

4. Increase in weight occurs essentially as a result of raised exchange of extracellular fluid, the amount of which increases at a quicker rate than does the weight of the animal. The fat content in the organism is thereby often reduced. There is no direct relationship between the dose of the radioactive phosphorus introduced and the rate of increase in extracellular fluid exchange.

5. On administration of radioactive phosphorus in the organism of young growing animals no raised exchange of extracellular fluid was observed, though the weight of the animals increased due to tissue growth. Thus, growth energy is not completely suppressed by radioactivity. However, comparison of the rate of growth of irradiated animals with the controls shows that radioactive phosphorus partially inhibits growth energy.

6. Changes in the energy processes on administration of radioactive phosphorus are of a diphasic character. In the first 15 days inhibition of the energy processes was observed, seen to be particularly marked when calculated per m^2 body surface and per liter of extracellular fluid, which shows impairment of the functional condition of the organism. After 15 days the energy processes start to rise, and at the end of the month often exceed the initial level.

7. Suppression of the energy processes is connected with inhibition of oxygen consumption in the functioning protoplasmic mass.

8. After administration of radioactive phosphorus in goats and sheep a decline in the amount of hemoglobin and erythrocytes is seen, with simultaneous increase in color index.

Lyov Zoo-Veterinary Institute.

STUDY OF PENETRABILITY OF ANIMAL SKIN BY SULFUR PREPARATIONS WITH USE OF S^{35}

A. N. Yunin

1. The efficacy of the campaign against ectoparasites and pest insects in farm animals and the action of various acaricidal and insecticidal preparations on micro- and macroorganisms depends on the capacity of the preparations to penetrate the skin and enter the organism.

The objects of the work were: to study the speed of penetration of the sulfur preparations through the skin of sheep and rabbits in relation to the mode of administration; to make clear the conditions influencing skin penetrability, and also to establish the times and paths of sulfur excretion from the organism.

2. Relatively swift penetration through the rabbits and sheep skin of labeled bisethyloxanthogen (S^{35}) in the form of an aqueous potassium soap emulsion was found. The speed of penetration of the preparation was estimated at 10-15 mins. The maximum concentration of S^{35} in the blood was observed starting several hours after treatment, up to three days. In the next 10-15 days the radioactivity of the blood did not exceed 50% above the original level.

3. Alcoholic solutions of bisethyloxanthogen penetrated the animal skin in a much shorter time. 5-10 mins after applying the preparation to the skin an appreciable amount of radioactive sulfur was observed in the blood. The maximum concentration was observed in the first three hours, then it fell to a definite level.

which level persisted during the 48-hour period of observation.

4. Colloidal sulfur in an oily base penetrates rabbit skin in 10-15 min and sheep skin in 10-20 min. Radioactive sulfur was still found in appreciable quantities in the blood in 15-20 days; later only traces of it were detected.

5. Colloidal sulfur dusts applied to the skin penetrated it slowly in small doses. An appreciable amount of radioactive sulfur in the blood in rabbits appeared within 30-50 mins, in sheep in 40-60 mins.

6. An aqueous solution of sodium sulfide, and also an aqueous suspension of colloidal sulfur did not penetrate undamaged skin.

7. The speed of penetration of sulfur through the skin depends on the temperature of the surroundings and the physicochemical properties of the solvent itself (water, alcohol, oil, etc.).

Rapidly evaporating solvents (alcohol) at an environmental temperature of 10 to 20°C and relative humidity of 75% persist on the animal skin for up to two hours, and aqueous solvents for up to one day.

Oily bases (plant and mineral oils) at a temperature of 10 to 20°C and relative humidity of 75% stay on the skin and hair up to 3-6 days.

With a rise in temperature of the surroundings of more than 20° the speed of penetration of the substance through the skin is temporarily increased, and is reduced when the temperature falls to between 3 and 0°C.

Excretion of the radioactive sulfur in sheep occurs mainly in the urine, feces, and suint in the first and third days after application to the skin. In the urine, the sulfur isotope appeared within the first two hours, and in the feces it was found in 5 hours. The two-day maximum of radioactive sulfur was excreted by the urine—94%, the feces—6%, and suint—10%, on conversion to 1 g dry substance.

The duration of sulfur excretion in the urine was 40-42 days, in the feces 30-36 days, and in sweat 20-35 days. Similar results regarding times of excretion were obtained in rabbits.

A high sulfur content was observed in sheep skin. This was connected with the excretory functions of the skin and also with the fact that in part elementary sulfur is involved in the process of synthesis of the wool proteins (keratin).

9. Application of externally applied tracer doses of radioactive sulfur in the study of skin penetrability did not produce visible clinical deviations in the healthy animals, nor noticeable deviations from normal in the blood picture.

All-Union Scientific Research Institute of Veterinary
Health and Ectoparasitology

PARTICIPATION OF FODDER CHLOROPHYL IN SYNTHESIS OF HEMOGLOBIN

F. V. Zakharova

1. On the basis of experimental data it was established that chlorophyll participates in the regeneration of hemoglobin and enhances the function of the blood-forming organs. The action of chlorophyll on blood formation is due to the chemical affinity of chlorophyll and hemoglobin, both being pyrrole derivatives.

2. Experimental application of C^{14} -labelled crystalline chlorophyll helped to explain the mechanism of chlorophyll influence on blood formation.

3. Investigations carried out on rabbits and young bulls showed that on oral administration of labelled chlorophyll radioactivity was found in the blood. The speed of absorption depends on the form of the preparation administered. Absorption of the radioactive substance in the blood runs a different course depending on species, age and individual character of the animals.

4. The degree of utilization of chlorophyll in biosynthesis of hemoglobin was estimated by the incorporation in the hemoglobin of radioactive substance introduced in the organism in the form of C^{14} -labelled crystalline chlorophyll. The radioactive substance entering the blood was quickly utilized by the organism; in the blood it was found in the hemoglobin of the red cells. The radioactive substance was still present in the hemoglobin after nine days.

5. The selective capacity of the blood-forming organs for chlorophyll derivatives was established by the content of large amounts of radioactive substance in the bone marrow and liver. In the functional activity of the blood-forming organs the radioactive substance is utilized for formation of the hemoglobin, in the first place from the liver, then from the bone marrow—more rapidly from the bone marrow of the tube bones, and more slowly from the breastbone.

6. The presence of radioactivity in the heme, liver, and bone marrow of rabbits and bulls shows that chlorophyll actually takes part in animal blood formation, being the plastic material for hemoglobin synthesis, yielding the semifinished products—porphyrins.

Because of this property of chlorophyll it may be considered as one of the factors in feeding, contributing to enhancement of the value of winter fodder rations, thus preventing the development of extrinsic anemia in animals in the winter-spring period.

All-Union Scientific Research Institute of
Animal Breeding

INFLUENCE OF VITAMIN INTAKE ON PHOSPHORUS METABOLISM IN ANIMALS

N. I. Ovsyanov

Assimilation and speed of metabolism of mineral substances in the animal organism depends on many factors, one of them being vitamin nutrition. In regulation of mineral substances, in particular phosphorus, by the animal organism, it is necessary that the organism be supplied with vitamins.

Experiments designed to demonstrate the influence of vitamin C, A and D supply on phosphorus metabolism were conducted on young guinea pigs and white rats. The animals were kept for several weeks on diets varying in vitamin C (guinea pigs), A and D (white rats) content and after administration of radioactive phosphorus in the form of Na_2HPO_4 , a determination was made of distribution and specific activity of phosphorus in the internal organs, in the femoral muscles, in the epiphysis and diaphysis of the femur, in the blood, in the stomach contents, and also in the feces and urine.

With vitamin C deficient rations in guinea pigs it was noted that there was acceleration of phosphorus uptake in the blood, more rapid excretion in the feces and a perceptible fall in the rate of phosphorus metabolism in the liver, kidneys, and to a lesser extent, in the spleen. The more rapid rate of excretion of this element in the feces was apparently associated with reduced phosphorus incorporation capacity of the liver,

kidneys and spleen.

In the first 3 hours after administration of radioactive phosphorus, the intensity of incorporation in the organs, and particularly in the bones of rats not receiving vitamin D, was higher than in rats kept on a full-value diet, despite the higher blood P^{32} content in the latter. The maximum incorporation of P^{32} in the tissues of the lungs, spleen, the muscles, and particularly in the bones was observed much earlier in rats not receiving vitamin D. However, on the next and following days phosphorus was less intensely incorporated in the organs and tissues and was more swiftly excreted in rats not receiving vitamin D than by the normally fed animals.

Absence of vitamin A in the ration of white rats produced a fall in phosphorus incorporation in the tissues of the heart, liver, spleen, kidneys, and muscles in the first 3 hours after administration.

Siberian Veterinary Scientific Research Institute

DISTRIBUTION OF PARATYPHOID VACCINES IN ORGANISM

I. N. Arkhangelsky and O. A. Berdink

Antigen distribution in the organs and tissues and rapidity of excretion from the organism are of great importance in the problem of postvaccination immunity.

The method of labeled atoms opens up new possibilities in the study of this process, for their use can provide a direct answer to the question of the duration of the labeled antigen in the organism and the pattern of its distribution.

Although the problems of the pathogenesis of brucellosis and distribution in the organism of typhoid fever antigen have to some extent been investigated by means of labeled atoms, no use has been made of isotopes in study of alum-precipitated paratyphoid vaccines.

In the experiments six vaccine variants were prepared from bacteria containing labeled phosphorus—formol vaccine, alum-precipitated formol vaccine, broth vaccine, alum precipitated broth vaccine, semiliquid vaccine and alum-precipitated semiliquid vaccine.

The bacteria for these vaccines were incubated on 3% solid agar containing radioactive phosphorus; then the bacteria were washed off with normal saline and freed from the nutritive medium residues in a centrifuge. The same number of bacteria containing radioactive phosphorus were added to the prepared medium (bouillon, semiliquid agar, etc.).

Guinea pigs were immunized with each of the variants and were sacrificed 3, 5, 15 and 21 days after vaccination, and preparations were made from their organs for determination of labeled phosphorus.

The experiments showed that in 3-5 days regional lymphatic nodes contained a maximum amount of radioactive phosphorus, and consequently of antigen. The organs rich in reticuloendothelial elements—the liver, spleen, bone marrow—usually retained antigen in larger quantities than the lungs, heart and kidneys. In the majority of cases the brain in the first 3-5 days after vaccination showed no, or minimal, antigen content.

Within 15-21 days the quantity of antigen in the organs of the reticuloendothelial system was at the maximum. The central nervous system at this time, though containing radioactive phosphorus, had a lower content than other tissues. Hence it can be assumed that it is the contact between antigen and reticuloendothelial tissue which is of paramount importance in the immunization process.

Alum-precipitated antigen was absorbed more slowly than an analogous non-alum preparation, contributing

to a prolonged antigen level in the organism. This was particularly evident in vaccines prepared in normal saline (formol vaccines), and to a lesser degree in the broth vaccines and those containing semiliquid agar.

Uzbekistan Agricultural Institute

DIFFUSION IN GUINEA PIG ORGANISM OF ORALLY ADMINISTERED

P^{32} -LABELED BCG MYCOBACTERIA

N. S. Stolygvo

1. It is useful to employ ultrasonic energy in the preparation for biological experiment of P^{32} -labeled *Mycobacterium tuberculosis* to ensure more thorough removal of the radioactive phosphorus, loosely bound to the bacterial cells, and also in the homogenization of the mycobacterial suspensions. In the present investigation use was made of P^{32} -labeled *Mycobacterium tuberculosis* in BCG, washed free from the loosely bound P^{32} , and homogenized by 4-minute processing of the suspension by ultrasonics (380 kilohertz at an intensity of 10 watt/cm²) with subsequent centrifugation and replacement of suspending fluid.

2. The object of the investigation was to trace the paths of penetration and diffusion in the organism of the labeled *Mycobacterium tuberculosis* contained in the BCG strain vaccine introduced by mouth (in line with the method of anti-tuberculosis vaccination proposed by de Assis). The experiments were performed on 40 chloroformed guinea pigs which were investigated 2 and 24 hours after administration of the BCG mycobacteria (50 mg bacterial mass in 0.5 ml normal saline).

3. 2 hours after administration of the BCG mycobacteria, radioactivity was noted in the stomach contents, duodenum and small intestine and, in half of the animals, in the colon contents. In 24 hours considerable radioactivity was detected in the colon contents of all animals.

Investigation of the washed digestive tract tissues showed that, 2 hours after administration of the mycobacteria, considerable radioactivity was fixed only in the lymphoid system of the intestines (in the Peyerovskiy's nodules), and was absent from the stomach walls and all sections of the intestines.

4. Some of the BCG mycobacteria administered by mouth quickly penetrated the cervical lymphatic nodes from the pharyngeal lymphoid tissue. In addition, within two hours of administration of the mycobacteria radioactivity was found in the lymph nodes of the mesenterium and in the majority of cases in the tracheobronchial nodes. Radioactivity in the lymphatic nodes increased in 24 hours.

5. In healthy guinea pigs receiving a sufficient amount of ascorbic acid, appreciable radioactivity was seen in the blood within only 2 hours and it completely disappeared in 24 hours, but was found in the lymphatic nodes, in bone marrow and in the internal organs. In guinea pigs with vitamin C deficiency, in all cases, radioactivity was detected in circulating blood only 24 hours after introduction of the mycobacteria.

6. Radioactivity was established soon after administration of the mycobacteria in lung tissue, being almost always considerably higher in the upper lobes than in the lower ones.

7. In healthy guinea pigs, 24 hours after oral administration of labeled BCG mycobacteria, in all cases, appreciable radioactivity was found in the urine, but in vitamin C deficient animals it was not present in the urine or present only in insignificant amounts. The rate of urine excretion of P^{32} compounds which readily diffuse through the kidneys may in the given experiment be an index of the intensity of the rate of destruction of mycobacteria in the organism, with attendant liberation of P^{32} from the bacterial cells.

Institute of Microbiology, Latvian SSR Academy of Sciences

NATURE OF CARBOHYDRATE CONVERSION IN THE CAVITY FLUID OF MULBERRY SILKWORM (BOMBYX MORI) IN THE METAMORPHOSIS PERIOD

E. I. Vyskrebentseva

In order to clarify the nature of conversion of carbohydrates in the cavity fluid of the mulberry silkworm in the period of metamorphosis, uniformly labeled C^{14} sucrose, radioactive carbon dioxide ($C^{14}O_2$) and also various glycolysis inhibitors (NaF and CH_3COOH) were employed.

It was shown that oxidation of sugar in the cavity fluid produces phosphoric esters and organic acids.

The fluoride salt and monofluoroacetic acid inhibit organic acid synthesis by considerably reducing formation of pyruvic acid from the introduced sugar, which gives grounds for supposing that pyruvic acid is a product of glycolysis in the cavity liquid.

Analysis of the phosphorus compounds of the acid-soluble fraction showed the absence of phosphoric esters of sugars which are intermediate products of glycolysis and the pentose cycle, and the presence of phosphorylated higher alcohols of unknown structure. Inhibition of synthesis of one of the phosphorylated alcohols, not only by CH_3COOH , but also by NaF, indicates that formation of it occurs not in oxidation of the phosphoglycerol aldehyde, but at later stages of glycolysis by means of transfer of hydrogen from the pyruvate, or the acids formed from it, to the corresponding phosphoric esters.

The presence of radioactivity in malic, fumaric and succinic acids when labeled sugar is administered in the cavity fluid shows that conversion of pyruvic acid is essentially linked with its role in dicarboxylic acid synthesis by means of carboxylation. Synthesis of tricarboxylic acids, and in particular citric acid, is insignificant. The latter is formed chiefly, not from carbohydrates, but as a result of carboxylation of organic acids, probably decomposition products of fats. This fact strongly suggests that in the cavity fluid anaerobic oxidation of carbohydrates is the predominant process.

Sucrose introduced in the cavity fluid may be subjected not only to oxidative transformations, but may be used in the synthesis of a complex unidentified high molecular weight phosphorus compound. On suppression of glycolysis this method of transformation predominates.

Study of carbohydrate transformation during metamorphosis showed that hystolysis substantially reduces the capacity of the cavity fluid to synthesize phosphoric esters and organic acids from the introduced sugar, while, in the course of histogenesis and differentiation, this capacity is restored.

K. A. Timiryazev Institute of Plant Physiology
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VI. AGROCHEMISTRY AND SOIL SCIENCE

STUDY OF METHODS OF SUPERPHOSPHATE PLACEMENT WITH VARIOUS AGRICULTURAL CROPS

I. V. Gulyakin and P. M. Smirnov

In studying methods of superphosphate placement, the radioisotopic method was applied, which allows for a more accurate assessment of the magnitude and rate of plant assimilation of fertilizer and soil phosphorus.

Small scale growth experiments were conducted with corn, potatoes, oats and winter wheat to demonstrate the influence of various methods of introduction of superphosphate and kindred fertilizers and also of soil liming on plant phosphorus assimilation.

The investigations showed that the method of introduction of superphosphate, and also joint compost-superphosphate application, nitrogen fertilizers, and soil liming, exert a considerable influence on plant phosphorus assimilation from fertilizer and soil.

Comparison of deep and shallow placement of the superphosphate shows that in the first case plants assimilate much more phosphorus from the fertilizer and also make more efficient use of the soil phosphorus.

With shallow introduction of superphosphate, fairly intensive entry of fertilizer phosphorus in the plant is witnessed only in the course of the first two weeks after germination, and later sharply falls, while when the superphosphate is located deep in the soil, entry of phosphorus increases in line with plant growth.

The highest plant phosphorus assimilation from superphosphate during the entire growth period was achieved by a combination of deep placement of fertilizer in rows in the sowing of oats, or in the holes in planting of potatoes and sowing of corn. With deep placement of superphosphate as basic fertilizer in conjunction with local introduction, greater utilization by the plant of soil phosphorus is observed. With surface introduction of superphosphate in spring nutrition of winter wheat, phosphorus utilization by plants was not high and to a large degree depended on the time of introduction of the supplementary fertilizer. On early introduction of superphosphate in the supplementary fertilizer (in frozen soil) plant utilization of the fertilizer phosphorus was two to three times greater than on late supplementary nutrition (before harrowing of the winter crops).

Introduction of compost together with superphosphate improved plant utilization both of fertilizer phosphorus and soil phosphorus. In the experiments with corn, on introduction of a comparatively small amount of compost (3 centner/hectare) together with superphosphate (3 centner/hectare) the compost exerted a positive effect on plant utilization of fertilizer phosphorus. Increase in compost amount to 50 centner/hectare had no greater influence on plant assimilation of superphosphate phosphorus than did the smaller dose of compost (3 centner/hectare). The compost introduced together with the superphosphate in the plant in large amount may in the first period somewhat reduce entry of phosphorus from the superphosphate.

Addition to the superphosphate and compost mixture of 5 centner/hectare lime reduced plant utilization of fertilizer phosphorus. However, the negative effect of the lime, when introduced along with superphosphate, on entry of fertilizer phosphorus, was dependant on the quality of the soil.

In strongly acid peaty podzolic soil corn utilization of phosphorus from superphosphate when introduced together with compost and with liming of the soil was much higher in terms of hydrolytic acidity than on introduction of superphosphate and compost mixed with 5 centner/hectare lime.

In land under potatoes introduction of superphosphate together with nitrogen fertilizers in the first period somewhat reduced the phosphorus entry in the plant from the superphosphate. However, later these fertilizers exerted a positive influence on plant assimilation of phosphorus from the superphosphate.

K. A. Timiryazev Moscow Agricultural Academy

THE INFLUENCE OF HUMUS AND PEAT MOSS ON THE INTAKE OF PHOSPHORUS AND CALCIUM INTO PLANTS

A. V. Peterburgsky

In a number of field and vegetation experiments using P^{32} and Ca^{45} a study was made of the intake of phosphorus and calcium into the aboveground portion of oat, clover, corn, potato, beet and cabbage plants. Fertilizers containing labeled superphosphate or labeled lime were introduced into the soil in combination with humus, peat moss or compost (in small doses).

In two vegetation experiments with oats conducted on acidic, slightly argillaceous soil (pH 4.5), it was noted that mixing NPK (of which the P is labeled superphosphate) with humus ("household earth") is accompanied by a decrease in the intake of P^{32} in the course of approximately one month, in comparison with the introduction of the mineral fertilizers without humus.

The addition of a small dose of lime (in an amount equivalent to 0.1 of the hydrolytic acidity of the soil) to the mixture of NPK and humus increases somewhat the intake of P^{32} into the oat plant. Lime with NPK (without humus) does not substantially influence P^{32} intake of the plants.

Mixing NPK with nonacidic lowland peat moss (pH 6.2) resulted in a lowering of not only the relative but also the absolute P^{32} content in the yield of oats.

Evidently the phosphoric acid anion is bound by both peat moss and humus. On the same soil the restraining influence of humus on phosphorus intake was shown also in an experiment with clover. The yield of oats and clover increased negligibly with the addition of humus.

When NPK was mixed with humus and labeled lime, in the first period there was also observed a notable reduction in the intake of Ca^{45} into oats.

The same humus was used in a vegetation experiment with the edible beet plant on acidic, heavily argillaceous soil (pH 4.5). It was ascertained that there was somewhat less P^{32} in the leaves in the first period than without the addition of humus. This was not noted when NPK was mixed with a small dose of lime. Neither humus nor lime substantially influenced the yield. In a field experiment with corn on acidic (pH 4.5), sandy soil, the above mentioned lowland peat moss, in a dose of 5 tons per hectare, implanted in holes together with superphosphate, increased somewhat the yield of the green mass, but curtailed the intake of P^{32} .

In a second field experiment with the same plant on acidic, argillaceous soil (pH 4.5), humus deposited in holes in the amount of one ton per hectare strongly increased the yield, particularly of the corn ears. The addition of labeled lime to the humus (in the amount of 0.01 to 0.05 of the hydrolytic acidity of the soil) increased its positive effect. The intake of Ca^{45} into the aboveground portion in some cases was slightly decreased in the first period under the influence of the humus, but the absolute content of Ca^{45} in the yield increased.

An analogous condition was noted also in a field experiment with cabbage on nonacidic, heavily argillaceous soil. When humus and labeled superphosphate were deposited in holes, both the yield and the intake of P^{32} into the plants increased.

Two experiments were conducted with the potato on sandy, nonacidic soils. In the first of them humus from a peat moss-phosphorite compost, when deposited in holes together with superphosphate, checked the intake of P^{32} into the leaves and slightly increased the yield. In the second experiment a substantial influence of such a compost was not noted, either on the yield or on the absorption of P^{32} .

Thus, in acidic soils organic admixtures not infrequently decrease the absorption by plants of phosphorus and calcium from fertilizers in the beginning of vegetation. In soils with a reactivity close to neutral this is not noted; at times the intake of P^{32} and Ca^{45} into plants is even increased.

The K. A. Timiryazev Moscow Agricultural Academy

THE INFLUENCE OF CERTAIN CONDITIONS ON THE AVAILABILITY OF PHOSPHORUS TO PLANTS

P. A. Dmitrenko and V. S. Shturmova

In research employing the method of labeled atoms, a study was made of the influence on the availability of phosphorus to plants of the nature of the distribution of phosphorus fertilizers in the soil with respect to plant roots, and of concomitant fertilizing, particularly with lime.

In experiments dealing with the first question, the task was one of making clear with which size granules of superphosphate do there exist the most favorable conditions for the intake of phosphorus into plants.

In field experiments of short duration conducted on a limited scale, a study was made of the intake of marked phosphorus into oat and millet plants in relation to dose and size of granules of superphosphate, which was introduced into the rows; in similar experiments with winter wheat superphosphate was applied by scattering.

By means of observations of the intake of radioactive phosphorus into plants, it was established that the most favorable conditions for feeding plants with phosphorus in the initial period of their growth and development are created by using superphosphate with granules of minimal size—1 to 2 mm and smaller.

With an increase in the size of the granules up to 5 to 7 mm in diameter, the accessibility of phosphorus is reduced to a greater extent than the dose of superphosphate was decreased; this is explained by an increase in the "positional" inaccessibility of phosphorus to part of the plants, which in the final analysis results in variegation in the development and yield of the plants on a fertilized field.

On the basis of experiments conducted, the conclusion suggests itself that it would be expedient to introduce certain changes in the existing specifications for granulated superphosphate. In particular, it would be possible to include in the composition of granulated superphosphate a large portion of granules 1 to 2 mm in size and smaller.

In vegetation experiments of short duration with the sugar beet, flax, lupine and pea, the use of lime in combination with superphosphate on gray forest soil (in the amount of 5 centners per hectare) lowered the intake of phosphorus during the first period of development of the plants. Among other crops (hemp, rye, oats, barley, winter wheat, potatoes, sunflower seeds, corn, clover, alfalfa), the use of a like dose of lime did not decrease the intake of phosphorus into the plants.

Mixing superphosphate with large doses of lime (4 tons per hectare) led to a notable decrease in intake of phosphorus into the plants of such crops as peas, alfalfa, clover, lupine, flax, corn, sunflower seed and potatoes, but did not substantially influence phosphorus intake among hemp, rye, oat and barley plants.

In a vegetation experiment using the method of isolated feeding, it was established that the decreased availability of phosphorus to a plant, when used in combination with lime, is explained by the decreased activity of the phosphorus under the influence of the calcium of the lime.

The Ukrainian Scientific Research Institute of Farming
of the Academy of Agricultural Sciences of the USSR

THE USE OF P^{32} IN A STUDY OF THE INFLUENCE OF THE
COMPOSITION OF ORGANOMINERAL MIXTURES AND THEIR DISTRIBUTION
IN THE SOIL ON THE PHOSPHORUS FEEDING OF SPRING WHEAT

V. M. Motky, V. A. Rabinovich, O. V. Kurovskaya and K. N. Arkhireeva

Along with the widespread use of organomineral fertilizer mixtures, a matter of some importance is the clarification of the role of mixing phosphorus fertilizers with humus and lime in the phosphorus feeding of plants.

In experiments conducted in 1955 and 56, it was established that mixing superphosphate with humus creates more favorable conditions for the assimilation of phosphorus by plants, apparently together with a reduction of phosphate retrogradation in the soil.

Introduction of lime into a mixture of superphosphate or calcium phosphate with humus results in a reduction in the assimilation of phosphorus by plants; in the case of superphosphate this is evidently explained by the conversion of phosphorus compounds into forms not readily accessible to plants, and in the case of calcium phosphate—by the reduction of its solubility, which is linked with alkalization of the medium.

The positive influence on the phosphorus feeding of plants of mixing superphosphate with humus and the negative effect of lime introduced into the fertilizer mixture are manifested in the early periods of growth and remain until the harvest, leading thereby to corresponding changes in the yield.

On the basis of these data, the introduction of lime into a fertilizer mixture of superphosphate or phosphorus meal with humus must be considered inexpedient for well or moderately cultivated soils, and also for poorly cultivated soils containing a small amount of active aluminum.

The plants which are located directly in the row that is fertilized enjoy the most favorable conditions for phosphorus feeding. Plants separated from the fertilization foci by an intermediate row of plants assimilate phosphorus from the fertilizer in extremely small amounts, and the yield of grain from these rows is close to that of the controls. Therefore, that method of applying fertilizers is expedient which guarantees uniform distribution of the fertilizers with respect to each plant (application by row or uniform scattering).

The Northwestern Scientific Research Institute of
Agriculture

A DEMONSTRATION OF THE REUTILIZABILITY OF CALCIUM IN PLANTS
USING THE METHOD OF LABELED ATOMS

N. P. Krasinsky*, G. V. Barinov, V. E. Kiselev and O. K. Sevrova

Among plant physiologists and agricultural chemists it is a widespread notion that the calcium in plants is not reutilized. This notion, however, is based on data the correctness of which has still not been proved, and requires careful verification with the method of labeled atoms.

Until the present time there has been very little research employing Ca^{45} which indicates that calcium is capable of being reutilized.

We conducted research with $Ca^{45}Cl_2$ on the question of the reutilizability of calcium in plant organisms.

*deceased

The factual material assembled, together with a consideration of the data referred to above, appearing in the literature, permit one to draw the following conclusions.

1. At the present time it can be considered proved by means of the method of labeled atoms that, at least among a number of plants, reutilization of calcium exists.
2. There is a necessity for expanded research employing radioactive isotopes in order to establish the conditions favoring reutilization of calcium among different plants of unequal age and development.
3. A study of the reutilization of calcium has great physiological significance with respect to general principles and also represents a matter of considerable interest to agricultural chemists and agronomists.

The Western Siberian Branch of the Academy of
Sciences of the USSR

THE USE OF P^{32} IN A STUDY OF THE INTAKE OF THE
PHOSPHORUS OF FERTILIZERS INTO PLANTS

N. I. Kukhareenko

The use of labeled phosphorus in field, vegetation and laboratory experiments made it possible to explain a number of factors influencing the intake into plants of phosphorus from fertilizers.

The influence of the content of slightly soluble phosphorus compounds in the soil on the entry into plants of phosphorus from superphosphate was detected in vegetation experiments with millet grown on four soils; the more of the slightly soluble compounds of phosphorus in the soil, the less did the phosphorus from superphosphate enter the plants, and vice versa.

Thus, when the phosphorus content of the soil equaled 17 to 21 mg of P_2O_5 per 100 g of soil (in a 0.5 N hydrochloric acid extract), only 4 to 10% of the general phosphorus content of a plant entered into the plant from superphosphate. When the phosphorus content of the soil was 8 to 9 mg of P_2O_5 per 100 g of soil, 55 to 60% entered the plant.

In a laboratory experiment a study was made of the influence on the intake of phosphorus into rye sprouts of the time of interaction of monocalcium phosphate labeled with radioactive phosphorus with rich black earth containing a slight amount of humus. With an increase in the time of interaction, the intake of phosphorus into plants from monocalcium phosphate decreased. Thus, when monocalcium phosphate was applied 15 days before sowing, 14% of the phosphorus contained in the monocalcium phosphate entered into the plants; when it was applied 15 days later (on the day of sowing), 20% entered.

Under the conditions of the given experiment, the use of labeled phosphorus made it possible to discern negligible changes in the transformation of phosphorus fertilizers in the soil from certain forms into others depending upon the duration of interaction with the soil, changes which exert an influence on the intake of phosphorus from fertilizers into plants, but which cannot be detected by phosphorus determination with F. V. Chirikov's method.

In a field experiment with millet on subsoiled, black meadow earth, a study was made of the influence of the different distribution of superphosphate (labeled with P^{32}) relative to the seeds in a row. In this connection it was established that the greatest intake of the phosphorus of superphosphate during the early period of growth (on the 2nd and 10th day after the appearance of sprouts) is detected when the fertilizer is deposited together with the seeds. During a later period of plant growth (31 days after the appearance of sprouts), the

greatest consumption of phosphorus by the plants occurred when superphosphate was introduced into the rows at a depth 10 cm greater than that of the seeds.

The Ukrainian Scientific Research Institute of Farming

THE USE OF RADIOACTIVE INDICATORS IN A STUDY OF FEEDING CONDITIONS AND THE EFFECT OF NUCLEAR RADIATION ON PLANTS

P. A. Vlasyyuk

The method of labeled atoms is used in order to obtain a deeper understanding of the vital processes of plant and animal organisms with the aim of increasing their productivity.

In our research, labeled atoms and small doses of radioactive ionizing radiation were used to study the improvement of feeding conditions and to increase the productivity of agricultural crops.

The influence on plants of levels of ionizing radiation close to natural radioactivity is brought about by treating the seeds or fertilizers prior to sowing, by introducing radioactive isotopes into the soil or into peat moss and humus mixtures in pots, and by using them to spray the leaves and flowers of plants.

By means of the method of labeled atoms, it was shown that metabolic exchange with the external environment begins in plants immediately after the first appearance of enzymatic processes during the swelling of seeds. Thus, the necessity of introducing phosphorus fertilizers into the rows and drills at the time of sowing seeds and planting seedlings was substantiated; the equal effectiveness of organomineral mixtures and granules was demonstrated, a fact which provides a basis for the wide use of organomineral mixtures in the agricultural industry.

With respect to the assimilation of phosphorus from different fertilizers, for the first month superphosphate should be used, then pyrophosphate, and during the last month orthophosphate; a most important proposition of Soviet scientists was verified: sugars are formed principally in the leaves, while in the roots of the sugar beet they are deposited as reserves, and therefore the phosphate feeding of plants is highly significant in increasing saccharinity; it was shown that phosphorus is accumulated at points of growth, while calcium is accumulated in older organs, a fact which makes it possible to evolve a rational technique of applying fertilizers.

Manganese promotes the best utilization of sulfur, phosphorus and calcium by plants and a more economic expenditure of carbon, nitrogen, phosphorus and potassium in producing crops and improving the quality of agricultural products; manganese and copper are effective in promoting the transformation of nitrogen into protein, especially on peat soils. Labeled carbon from soil carbonates enters a plant as a result of the alkalinity of the environment. It was shown for the first time that a more intensive phosphorus alimentation of plants occurs, not in the course of the vital processes of soil bacteria, but after they have died off; for this reason sorptive forms of nutritive substances are better utilized by a plant than soluble forms. Sulfur and phosphorus metabolism and the formation of different amino acids is notably increased under the influence of manganese. In this regard, the sulfur of inorganic and organic compounds is found to a greater extent in reserve proteins rather than in structural proteins; in connection with this fact, the use of sulfate forms of potassium fertilizers is a reliable means of increasing the productivity of plants.

In the roots of the sugar beet, C^{14} was linked primarily with lysine and oxalic acid. In the leaves it was

combined primarily in tartaric acid and, considerably more slowly, in fumaric acid.

The action of small doses of ionizing radiation, which we consider a factor linking plant organisms phylogenetically, in the majority of cases resulted in an increased yield and the improved quality of various agricultural crops; in this connection the reaction of plant organisms to the radiation of the radioactive isotopes Zn^{65} , Co^{60} , Ca^{45} , S^{35} , P^{32} , and C^{14} , both when seeds were treated with their solutions and when they were included in nonroot alimentation, was characterized by a significant increase in productivity and the formation of biological buffer systems from glutathione and ascorbic acid which mitigated the harmful effect of excess radioactive isotopes.

A matter warranting attention is the reaction of plants to the joint application of weak solutions of herbicides and radioactive substances, in which there is observed not the suppression of the reactive capacity of weeds, but rather its increase; this increases their susceptibility to damage by smaller doses of herbicides.

It is necessary to conduct further research on the influence of ionizing radiation using isotopes with short half-lives with the aim of clarifying the mechanism of their biological action; in this study an exact calculation must be made of the conditions of the external environment, which determine the positive or negative effect of nuclear radiation on plants.

The Ukrainian Scientific Research Institute of
Plant Physiology

THE TRANSFER OF SUBSTANCES IN PEAT BOG SOIL AND THE INTAKE OF THE P_2O_5 OF SUPERPHOSPHATE INTO BARLEY PLANTS

T. N. Kulakovskaya

Research on questions connected with the transfer of phosphoric acid, which depends on the depth of ground water and the presence of vegetation and rainfall, was conducted on peat bog soil in various stages of cultivation from 1954 to 1956. Experiments were set up in lysimeters containing 0.64 m³ of peat bog soil.

Well-cultivated soil was found which had been in agricultural use for more than 25 years; virgin peat bog soil which had not been in agricultural use, but which was drained in 1914, served as poorly cultivated soil. There were no sharp differences in gross content of P_2O_5 between the indicated varieties of soil (0.34% P_2O_5 in the cultivated soil and 0.31% in the virgin soil). The amount of assimilated phosphorus was 30 to 40% greater on the cultivated soil than on the virgin soil.

As a result of the research conducted it was made clear that the transfer of phosphoric acid in peat bog soils proceeds more vigorously than in mineral soils.

On the 30th day after the introduction of fertilizers, phosphorus was detected in the soil at a depth of 50 cm.

The phosphoric acid of superphosphate is absorbed to a lesser extent in virgin soil, a fact which explains its greater activity. The intensification of transfer of phosphoric acid contributes to the absence of vegetation.

The elimination of rainfall resulted in a reduction of phosphoric acid transfer in the soil.

The intake of the phosphoric acid of superphosphate into barley plants was two to three times greater on the poorly cultivated soil than on that tilled for a long time.

The laminar distribution of superphosphate in soil caused a better intake of P_2O_5 into plants toward the

second half of the period of growth, a fact which, however, did not always result in increased yield on the soil under cultivation for a long time. The distribution of fertilizers in layers in the virgin peat bog soil resulted in their better utilization; this was evident in the increased yield.

The White Russian Scientific Research Institute
of Amelioration and Water Economy

THE INFLUENCE OF METHODS OF PROCESSING SOIL AND FERTILIZERS ON THE INTENSITY OF PHOSPHORUS INTAKE INTO ULYANOVKA WINTER WHEAT PLANTS

P. G. Buinova

The aim of the work was to study the nature of phosphorus intake into Ulyanovka winter wheat plants with respect to different methods of processing soil and introducing organic and mineral fertilizers.

Phosphorus was introduced into the plants through the roots from the soil and through the leaves by spraying. The intensity of intake of P^{32} was judged by the number of impulses recorded in a preparation of the plant.

The work was conducted according to the following plan:

1. Plowing with a three-frame plow at a depth of 65 to 70 cm, thus displacing the lower soil levels.
2. Treating the soil by T. S. Maltsev's method.
3. Ordinary plowing of the soil at a depth of 20 cm.

The soil treated by all three methods included fertilized and unfertilized portions.

The following data were obtained as a result of the research:

1. Phosphorus enters the winter wheat plant significantly more slowly in autumn than in summer.
2. The most rapid intake and transfer of phosphorus was observed among plants grown on the deeply plowed soil fertilized with organic and mineral fertilizers.
3. Relatively slow phosphorus intake was noted among the plants when ordinary plowing was employed, especially in the absence of fertilizers.
4. Over a more protracted period of time, 25 to 28 days, the most phosphorus is accumulated by plants not receiving fertilizers, against a background of ordinary and, especially, deep plowing.

A similar regularity was also observed with respect to the intensity of other physiological processes occurring in the plants (intensity of transpiration and photosynthesis).

Uniformity of phosphorus intake and other processes among plants was evidently observed because the plants grown on deeply plowed fields which received fertilizers had all that was necessary for their growth and development and possessed a higher vital impulse, a more intensive metabolism, than the plants grown on soil plowed in the ordinary fashion and which did not receive fertilizers, in which case not only was moisture insufficient, but evidently also mineral nutriment.

The plants grown on shallowly plowed and unfertilized soil accumulated phosphorus slowly. A higher gross yield was obtained with deep plowing of the soil and the use of fertilizers.

Thus, different technical methods of agriculture exert considerable influence on the physiological processes which make up the essence of plant metabolism. Therefore, the determination of the intensity of physiological processes in plants, especially the intensity of the intake, transfer and transformation of substances, is an important and reliable method of evaluating systems of technical agriculture procedures for increasing the yields of agricultural crops.

The M. Gorky Kazan Agricultural Institute

THE INFLUENCE OF TEMPERATURE CONDITIONS ON THE ASSIMILATION AND DISTRIBUTION OF NUTRITIVE ELEMENTS IN PLANTS

D. V. Strausberg

As a result of experiments conducted on water and soil crops lasting from 2 hours to 50 days, it was established that the temperature of the soil (and to a much lesser extent the temperature of the air) exerts a significant influence on the assimilation of nutritive elements by plants when fed through the roots.

It was established that the temperature of the air exerts an influence on the assimilation of phosphorus and its transfer within plants when they are not fed through the roots. It was shown that temperature did not influence assimilation of CO_2 (determined with C^{14}) by plants, but lowering the temperature of the surrounding air had a negative effect on the outflow of assimilated substances, while lowering the temperature of the root-containing area promoted more vigorous excretion of C^{14} into the nutritive solution via the root system.

Lowering the temperature from 19-21° down to 3-7° impeded most strongly the assimilation of nitrogen by the plants, to a somewhat lesser extent that of phosphorus, then that of calcium and sulfur; potassium was assimilated best of all at the lowered temperature. When the temperature was lowered from 21-19° down to 12-11°, nitrogen was assimilated by the plants better than phosphorus.

When the temperature of the root-containing area was lowered (down to 3-7°) the plants suffered primarily from nitrogen deficiency. When the temperature of the root-containing layer was 10-12°, sufficiently low to be characteristic of the summer season of certain sections of the extreme North, and in particular the Kola Peninsula, the plants suffered primarily, to all appearances, from a lack of phosphorus.

Lowering the temperature of the soil had a different effect on the growth of different plants, their assimilation of nutritive elements and on the distribution of the elements between the root system and aboveground organs. Increased concentration of NPK in the cold nutritive solution increased the assimilation of phosphorus by plants. No notable changes in the weight of the dry mass were observed in connection with this procedure. The use of nonroot sources of nutrition at lowered temperatures exerted a positive influence on plant growth and phosphorus accumulation.

The Kola Branch of the Academy of Sciences
of the USSR

THE INFLUENCE OF ORGANIC SUBSTANCES OF PETROLEUM ORIGIN ON THE INTAKE OF P^{32} AND Sr^{90} INTO PLANTS

D. M. Guseinov and R. E. Eyubov

In the task of increasing the productivity of agricultural crops, research on new types of organic fertilizers and the development of reasonable means of employing them is a matter of great practical and theoretical interest.

A great many experiments, laboratory, vegetation and field, have shown that small amounts of organic substances of petroleum origin in combination with mineral fertilizers do increase the productivity of agricultural crops. An increase in the growth and development of different agricultural crops was demonstrated under the influence of the introduction of small amounts of growth-inducing substances (up to 300 g per hectare), which were produced from organic substances of petroleum origin.

The positive effect of the substances indicated was principally evident in a strengthening of physiological and biochemical processes, the stimulation of plant growth and development, changes in microbiological processes in the soil and an increase in assimilated forms of nitrogen and phosphorus from the soil.

The method of labeled atoms was employed to study the influence of organic substances of petroleum origin on the intake of mineral substances into plants.

Laboratory, vegetation and field experiments showed that an organic substance of petroleum origin increases the intake of P^{32} and Sr^{90} into a plant.

The Institute of Soil Science and Agricultural
Chemistry of the Academy of Sciences of the
Azerbaijani SSR

THE INTAKE OF PHOSPHORUS, SULFUR AND CARBON INTO PLANTS FROM ORGANIC AND MINERAL FORMS OF THEIR COMPOUNDS

A. V. Manorik

Studies of the peculiarities of the utilization by plants of phosphorus, sulfur and carbon from organic and mineral forms of their compounds were conducted by calculating the accumulation of the radioisotopes of these elements in different plant organs. Along with the organic substances used in the experiment, tyrosine, methionine, cystine and vitamin B_1 , all containing radioactive sulfur or carbon, vegetable bulk containing radioactive phosphorus was used as fertilizer.

When S^{35} was applied to the leaves of buckwheat as sodium sulfate, methionine and vitamin B_1 , an appreciable accumulation of it was noted in the roots. At the same time the intake of S^{35} from methionine into the roots of the plants three hours after the beginning of the experiment was forty odd times greater than its intake from vitamin B_1 . When radioactive carbon was applied to the leaves as Na_2CO_3 and as tyrosine, the radioactivity of the roots was greater among the plants receiving carbon in the mineral form.

When buckwheat plants which had been cultivated in sand were transplanted into Knop's nutritive mixture containing radioactive sulfur in the form of vitamin B_1 or methionine as well as carbon in the form of tyrosine or sodium carbonate, after only 10 minutes there was observed a significant accumulation of these elements in the flowers and leaves of the plants. In the course of an hour the radioactivity of the flowers, which in the beginning had been much higher than that of the leaves, gradually decreased, while the radioactivity of the leaves increased. If in the case of application to the leaves radioactive carbon entered the roots more intensively from the mineral form (sodium carbonate), then in the case of introduction via the roots it entered more intensively from organic substances (tyrosine).

The intake of radioactive sulfur into plant leaves from different forms of its compounds depends upon the conditions of illumination (its duration and the nature of the light). At the same time it was noted that the composition of amino acids was more diverse in leaves to which sulfur was applied directly than in those leaves to which sulfur was transferred in the process of metabolism. This is apparently linked with the effect of radiation on the plant leaves. When the leaves were shaded the transfer of sulfur from the site of application into other leaves was at a minimum; at the same time its transfer into the roots was at a maximum in this instance.

The utilization of radioactive phosphorus to study the intake into plants of phosphorus from plant fragments was accomplished by obtaining the green mass of winter wheat and subsequently employing it as a fertilizer in a vegetation experiment. The P^{32} which was included in the composition of the vegetable mass used as fertilizer was detected in buckwheat plants during the very first days of growth, although its intake from superphosphate was more intensive. Infusion of the vegetable mass with liquid manure not only did not contribute to an increase in intake of P^{32} , but reduced it in comparison with intake from the noninfused vegetable mass. This influence of the infusion of plant fragments on the intensity of the intake of the phosphorus contained in them into buckwheat plants was noted also with respect to intake of S^{35} from the plant fragments.

The Ukrainian Scientific Research Institute of
Plant Physiology

INCREASING THE EFFECTIVENESS OF PHOSPHORUS FERTILIZERS USED WITH COTTON PLANTS IN IRRIGATION AGRICULTURE

I. M. Lipkind and Z. G. Kozodaeva

Research on sierozem - meadow and meadow soils of the Hissar Valley and on sierozem long under irrigation in the Vakhsh valley was conducted with the aim of showing the effectiveness of phosphorus fertilizers applied at different stages in the development of the cotton plant. Three ways of using phosphorus fertilizers at the time of sowing were tested: 1) application along with the seeds, 2) introduction of fertilizers into the row below the seeds at varying depths and 3) placing fertilizers at the side of the sown row at varying depths. P^{32} is taken into the cotton plant most intensively when fertilizers are deposited along with the seeds. This method provides the best prospects, but needs to be perfected. When fertilizers are buried in the soil, the most rapid and most intensive intake of P^{32} into the plants takes place when they are introduced below the seeds at a depth of approximately 5 cm; introduction of phosphorus at the side of the row considerably delays the time of its intake into the plants. The rate of intake into plants of the phosphorus of fertilizers increases in proportion to their growth and development and depends upon the method of introducing the fertilizers. When fertilizing is accomplished during the budding period, keeping the site of introduction of fertilizers close to the row promotes acceleration of the intake of phosphorus into the plant; instead of 23 to 30 days,

phosphorus enters the plant within 12 to 20 days after its introduction. This can be promoted by narrowing the space between the rows.

During the period of maximal utilization of phosphorus by the cotton plant, the period of fruit formation, proper fertilization guarantees the rapid (on the 2nd to 5th day) intake of phosphorus, as a result of maximal development of the root system of the plant, which guarantees contact with the foci of fertilization in the soil.

Later introduction of phosphorus fertilizers can be effective if watering of the cotton plant is carried out.

The research showed that, with normal watering, the phosphorus of the fertilizers may be partially transferred from the site of its introduction at 10 to 25 cm below the plants, and on the side, 4 to 5 cm from the focus of its distribution.

The data presented above verify the existence of favorable conditions for the effectiveness of late feeding of the cotton plant with phosphorus fertilizers resulting from the new agricultural techniques used in its cultivation. In connection with increasing the rate of intake of the phosphorus of fertilizers into plants, promoting its transfer in the soil and augmenting its utilization in proportion to the growth and development of the cotton plant, a new method of employing it is proposed which includes increasing the doses of phosphorus fertilizers in feedings taking place from budding to the beginning of ripening of the cotton.

When there is a sufficient reserve of active phosphorus present in the soil (more than 30 mg/kg according to Machigin), with this method there is less need to introduce fertilizers during plowing, but the use of small doses of phosphorus during sowing becomes effective.

A test of these proposals, worked out on the basis of application of the isotopic method, was conducted in field experiments from 1954 to 1956. The experiments fully vindicated themselves.

The principle of employing phosphorus fertilizers has already found application on collective and state farms. The proposal relative to strengthening the doses of phosphorus in feedings taking place in the later stages has entered into the agricultural specifications for cultivating cotton in Tadzhikistan since 1955.

The Institute of Soil Science, Amelioration and Irrigation
of the Academy of Sciences of the Tadzhik SSR

AN EVALUATION OF METHODS AND TIMES OF APPLYING NUTRITIVE PHOSPHORUS PREPARATIONS TO COTTON PLANTS

L. A. Filippov and N. S. Zhurbina

From 1954 to 1956 a study was made of the intake of phosphorus into cotton plants with different methods and times of applying nutritive phosphorus preparations. Granulated superphosphate and phosphoric acid solution prepared with labeled phosphorus were used in the research. The experiments were conducted chiefly under field conditions. The soils employed were chestnut brown, slightly humus and weakly saline.

The results of experiments studying the utilization of granulated superphosphate introduced into the rows show that, with an increase in the quota of superphosphate per hectare, the number of plants taking part in the assimilation of phosphorus fertilizers is increased.

This relationship was preserved from the sprouting stage to the beginning of budding. Utilization of granulated superphosphate by the cotton plant was increased significantly when it was introduced into the drill together with the seeds. In an experiment conducted in 1956, P^{32} was detected among 92.5% of the plants

when superphosphate was introduced into the drill along with the seeds (25 kg per hectare). It was established in laboratory experiments that when the granules are removed from the seeds by 2 cm and more, some plants do not utilize the superphosphate introduced into the rows with the seeds. Phosphoric acid, which is absorbed in great quantities by the germinating seeds and during sprouting, in a reutilization process guarantees for a protracted time an available phosphorus supply to the young plants. Granules implanted at a depth of 10 to 12 cm and those located at the side of the row begin to be utilized by the plants a month after sprouting. Granulated superphosphate implanted in the middle of the area between rows at a depth of 12 to 15 cm begins to be utilized by individual plants at the beginning of budding and, more intensively, at the end of budding and the beginning of blossoming. The intensity of its utilization increases significantly when the granules are brought closer to the row, up to 10 to 12 cm.

Utilization of granulated superphosphate introduced during budding into the middle of the area between rows at a depth of 10 to 12 cm depends upon the subsequent watering of the soil. Under arid conditions it is not utilized, while after plentiful rainfall or under irrigation conditions it may be utilized, to a lesser extent, however, in certain cases than when it was introduced following sprouting and kept within 10 to 12 cm of the row. During the years of the research there was observed an intensive assimilation of phosphoric acid solution, applied to the leaves in nonroot feedings. Thus, the most reasonable methods and times of applying nutritive phosphorus preparations to the cotton plant under the conditions of soil and climate prevailing in the southern USSR, those which will guarantee a continual supplementary supply of phosphorus to the plants, are the following: a) introduction of granulated superphosphate into the rows together with the seeds in the amount of about 50 kg per hectare or into the drills at sowing in the amount of about 25 kg per hectare, b) introduction of granulated superphosphate after sprouting at a depth of 12 to 15 cm and at a distance of 10 to 12 cm from the row, c) nonroot feeding during mass formation of the bolls.

The results of this research are quite in agreement with the data of field experiments conducted under these same conditions.

The Ukrainian Scientific Research Institute of
Irrigation Farming

THE METHOD OF LABELED ATOMS USED IN A STUDY OF MECHANIZED TECHNIQUES OF APPLYING PHOSPHORUS TO THE COTTON PLANT

F. I. Reshetnikov

With the use of the radioactive isotope of phosphorus, a study was made of the possible methods of mechanized application of phosphorus to the cotton plant.

The work was conducted under field conditions. In the experiments different times and methods of mechanized introduction of phosphorus were imitated.

As a result it was established that, from the point of view of the dates of applying phosphorus, the earliest time would be the use of superphosphate prior to sowing when the soil is plowed. This portion of fertilizer phosphorus, however, begins to be utilized by the cotton plant in the very latest period of its development. The introduction of phosphorus simultaneously with the sowing of seeds can be considered as an extra-early feeding of the cotton plant intended to satisfy the physiological requirements of the young plants from the 10th to the 20th day of growth after the appearance of shoots. The results of radiometric research, however, show that the number of plants which consume fertilizer phosphorus during this period of growth is very negligible. It was established that phosphorus introduced at the same time the seeds are sown begins to be assimilated by the

principal portion of the plants using it significantly later than 10 to 20 days after sprouting.

Fertilizer phosphorus is consumed by a negligible portion of the plants independently of whether it was introduced by a combination seeder during sowing or applied during cultivation.

The early dates for introducing phosphorus are determined ultimately by the proximity of the phosphorus "foci" with respect to the future growing plant. The author considers that the ultimate approximation of the "foci" of fertilizer phosphorus can be attained only by direct contact of the cotton seeds with the superphosphate, while this in turn is accomplished either by dusting the seeds or by introducing superphosphate into the rows beneath the seeds, and not by introduction prior to sowing or early feedings. Only in this way can one realize effective extra-early feeding of the future cotton plants with phosphorus.

It was shown by the method of labeled atoms that the existing method of introducing phosphorus fertilizer simultaneously with the sowing of seeds and in early feedings (especially its introduction during sowing) is far from perfect; it is, therefore, necessary to find simpler, cheaper, unencumbered methods of sowing cotton plants and more effective ways to increase the yield of cotton.

The Central Asian Scientific Research Institute of
Mechanization and Electrification of Irrigation Farming

THE INTAKE OF LABELED PHOSPHORUS INTO COTTON PLANTS ACCORDING TO STAGES OF GROWTH WHEN FOCAL INTRODUCTION OF GRANULATED SUPERPHOSPHATE IS EMPLOYED

E. I. Stolypin

The present work is an account of research accomplished in 1956 using superphosphate labeled with P^{32} , the purpose of which was to determine how, in the presence of focal distribution of fertilizer, phosphorus is utilized when the depth at which the fertilizer is laid is changed, as well as the distance from the focus to the hole in which the cotton plant is located, and also to clarify the extent and intensity of the intake of phosphorus from the fertilizer into the cotton plant during different stages of growth.

Experiments were conducted under field conditions on typical *sierozem* of the type found in alfalfa beds. By sowing at different dates, from April 25 through July 6, plants of different ages were obtained in six rows; at the time radioactive superphosphate was introduced, i.e., on July 16, the plants were in different stages of development, from the seed leaf stage to mass blossoming, the stage of fruit formation. Granulated radioactive superphosphate was introduced in foci opposite each cotton plant at the side of the area between the rows and at distances of 5, 10, 18 and 25 cm from the plant; it was deposited at a depth of 7 to 8 cm in the first two instances and at a depth of 13 to 15 cm in the second two. Plant specimens were taken for analysis on five days over the period extending from July 21 through August 11.

On the basis of experimental data we arrived at the following conclusions:

1. When the cotton plant possesses seed leaves and three or four true leaves, it does not utilize phosphorus from foci located at a distance of 10, 18 and 25 cm from the row. During this stage of growth it is necessary to guarantee a supply of phosphorus to the plant by introducing it into the rows during sowing. Early fertilization during the three- or four-leaf stage, even when fertilizers are introduced right next to the plant, cannot guarantee a good supply of phosphorus to the young plants, because in this case it will not begin to enter the plant immediately, but only after 20 to 25 days, a period coinciding with the onset of budding.

2. From the budding stage up until fruiting, the cotton plant assimilates well the phosphorus from foci located 18 to 25 cm from the row at a depth of 13 to 15 cm, 10 to 15 days after the introduction of superphosphate. A closer spacing of fertilizers during this period of growth cannot be considered expedient, because in this case it would not be possible to implant them deeply. Shallowly buried fertilizers (at a depth of 7 to 8 cm), even when brought as close as 5 cm to the row, are utilized to a significantly lesser extent than those located further from the row, but which are buried more deeply and are located in the zone into which extend the definitive roots.

The V. V. Kulbyshv Uzbekistan Agricultural Institute

AN APPLICATION OF P^{32} IN EXPERIMENTS WITH THE FERTILIZATION OF POTATOES AND VEGETABLE CROPS

A. I. Onishchenko and A. P. Vaganov

By means of the method of labeled atoms, an attempt was made to establish the most effective means of fertilizing the potato plant and a number of vegetable crops. Superphosphate and potassium hydrogen phosphate labeled by phosphorus were used in the experiments. Radioactive phosphorus was introduced in the amount of 12.5 and 25 μ c per plant at different depths (5, 10 and 15 cm) and distances from the row (5, 10, 15 and 35 cm). In experiments with the potato in 1954 and 1955, fertilizers were introduced in spring and summer plantings via ordinary and nonroot feeding. The research was conducted entirely under field conditions and on industrial crops.

In experiments with the potato conducted in 1954, a dry year, the initial intake of phosphorus was recorded on the 10th day after the beginning of the experiment. The most intensive phosphorus intake was noted where there was maximal proximity of fertilizers to plants. Fertilizers shallowly buried at a depth of 5 to 10 cm in the middle of the "interrow" in our experiment were scarcely effective, because the dryness of the upper soil layer impeded utilization of them by the plants.

Among the summer plantings of 1954, intake of P^{32} was recorded on the seventh day, while in the 1955 experiment it was recorded on the fifth. Shallowly buried fertilizer considerably removed from the plant, as was also the case with the spring planting, proved scarcely effective, while bringing the fertilizer closer to the plant proved highly effective with respect to the rate and quantity of phosphorus intake.

When nonroot feeding of the potato plant was employed, the rate of phosphorus intake into the plant was much higher than in the case of ordinary fertilization, and in only a day's time phosphorus was detected in the tubers. Upon analysis of tubers it was established that the greatest amount of P^{32} is accumulated in the apex of the tuber.

Intake of phosphorus into the carrot plant was noted on the fifth day after the beginning of the experiment, and in the cabbage plant on the second. When the fertilizer was shallowly buried, assimilation of phosphorus by the cabbage plant was accomplished more rapidly and in greater quantities than when it was more deeply buried; this can be explained by the particular development of the root system of the cabbage plant. Supplying phosphorus fertilizers to the onion plant during the late stages of its development is not effective, since phosphorus intake is not observed in this period.

The results of the research conducted lead to the conclusion that, for the purpose of fertilizing the potato plant and vegetable crops, among the existing cultivators or "plant-feeders" the KON-2,8 P and the KRN-2,8 cultivators can be recommended.

The Ukrainian Scientific Research Institute of Vegetable and
Potato Culture; The V. V. Dokuchaev Kharkov Agricultural
Institute

AN APPLICATION OF RADIOACTIVE PHOSPHORUS IN RESEARCH ON NONROOT FEEDING OF TOMATOES

V. A. Golikov

When the seedlings are taken from the hotbed and planted in the field, the root system of the tomato plant suffers a significant amount of damage. In the initial period after transplanting, the absorbing surface of the roots of the seedling is of negligible size, and this decreases the assimilation of phosphorus from the soil. In addition, the time of transplanting the seedlings to the field coincides among tomato plants with a critical period with respect to nitrogen and phosphorus feeding. Therefore, guaranteeing nutritive substances to the plants at this moment is extremely necessary.

Vegetation experiments with tomato seedlings showed that there is a definite difference in the time of intake of labeled phosphorus into plants when root and nonroot feedings are employed. While in the case of nonroot alimentation the principal mass of fertilizer phosphorus entered the plants during the first two days after feeding, when root feeding was employed P^{32} intake was more uniform and extended in time. During the 2 to 2 1/2 weeks after transplanting the seedlings to their permanent site, the tomatoes in the field utilized in extremely negligible amounts the fertilizers introduced into the hole when they were planted; this was because of the slow rate of growth of the root system. During the same period nonroot feeding under these conditions successfully guaranteed nutritive elements to the plants.

It was established in field experiments that in nonroot feeding fertilizer phosphorus is intensively conveyed to other organs, among which are the roots and fruit. When early feeding of the plants with phosphorus was employed, about 70% of the total amount of labeled phosphorus was detected in the fruits of the first cluster. In the second cluster 33% was detected, and in the third, 10%. When late phosphorus feeding of the plants was employed, in the fruits of the first cluster there was about 33%, in the second cluster, 53%, and in the third, 14%, of the amount of phosphorus which entered the fruits. In this connection it was natural to expect the acceleration of the ripening of the fruits of the first cluster in the case of early nonroot feeding, and hence even more abundant fruiting at the beginning of maturity.

Thus, the use of radioactive phosphorus in research on nonroot feeding of tomato plants enabled us to specify the proper time for nonroot alimentation and to establish the rate of intake of phosphorus into the plants, the path by which it is conveyed, and its accumulation in the fruit.

The Scientific Research Institute of Vegetable Culture

PROSPECTS FOR THE USE OF RADIOISOTOPES IN POMOLOGY

V. A. Kolesnikov

It has been established that assimilation of organic compounds takes place in both roots and leaves.

Fruit and berry plants have three basic types of root systems—of seed, stem and root origin—differing in their structure, distribution in the soil and biological properties, a fact which must be considered by the researcher.

The root systems of fruit crops are composed of roots in horizontal and strictly vertical directions. The first group of roots, depending upon soil zones, species and variety, on the whole are located at a depth of about 30 to 100 cm and occupy in diameter, from the second year after planting to the end of the life of the

plant, an area 1.5 to 2 times as large as that of the top of the tree. The second group of roots, the same factors considered, penetrate to a depth of about 10 cm.

In order to study the nutrition of fruit crops using labeled fertilizers, it is necessary to know beforehand the exact distribution of the principal portion of the roots.

The fundamental receivers of water and mineral substances are the absorptive root hairs; they are extremely mobile, since they are continually being formed, but within several days they become conducting. The conducting root hairs quickly die and are replaced by new ones. Research will provide more significant results if the dynamics of the growth of the roots and their mass throughout the experiment are known.

A definite rhythm has been established in the growth of the aboveground systems of fruit plants. It was shown that the growth of suckers among apple trees lasts for approximately 2 1/2 months in the Moscow district. When the suckers were irrigated they attained a growth of about 45 cm during this time; when mulching was performed growth reached 25 cm, and with ordinary care, only 15 cm. The longer the sucker, the greater the total surface area of the leaves. In setting up an experiment it is important to consider the time of active growth and the length of the suckers, as well as the surface area of the leaves. Fruit growers and physiologists have established the phenomenon of localization in fruit trees, that is an interconnection of individual roots with branches and of leaves with nearby flowers and fruits, etc. It has been experimentally established that, when labeled superphosphate was introduced into bores 30 to 40 cm deep into which water was subsequently added, radiophosphorus was detected in an apple tree (16 years old) on the 4th to the 6th day; when it was introduced into bores without water, and also in the case of application by spade or rake, radiophosphorus was not detected in the tree until the 14th day.

Use of the method of labeled atoms will provide more significant results if more consideration is given to the localization of nutritive elements within the plant, the rhythm in the growth of roots and branches, types of root systems and their distribution in the soil, the age of fruit formations (fruit twigs, rings etc.), the length of suckers, and the surface area of the leaves.

The success of the research and the reliability of the conclusions depends in large measure upon the joint effort of physiologists, biochemists and fruit growers.

The K. A. Timiryazev Moscow Agricultural Academy

THE USE OF P^{32} IN A STUDY OF METHODS OF FERTILIZING FRUIT TREES

E. D. Zelenskaya

The radioactive isotope of phosphorus, employed in a study of the dates and methods of introducing phosphorus fertilizers, showed that when superphosphate was introduced under the fruit trees in the spring the fertilizer phosphorus was absorbed by the arboreal plants very slowly and feebly. This was caused by the low reactivity of the phosphoric acid and the lack of contact of the fertilizers with the roots of the adult fruit trees. During a dry spring radioactive phosphorus was detected in the tree only 35-40 days following introduction of the fertilizer. Among young trees phosphorus was detected in an appreciable amount after 5 to 6 days.

The absorption of phosphorus from the fertilizer by the apple tree continues throughout the entire vegetation period if the fertilizer is introduced into moist soil (with watering). Even in the beginning of October, when the leaves on the trees have started to turn yellow, after 3 days following the introduction of superphosphate under young apple trees with watering them, P^{32} was detected in their leaves.

Most effective is the introduction of fertilizer in foci at a depth of 30 to 35 cm. When this method of

introduction is used, phosphorus is detected in the apple tree at the earliest time and in the greatest quantity. During the first half of the summer, a period of active growth, the phosphorus absorbed from the fertilizers is accumulated in the tops of the suckers and in the young leaves. In autumn there is a greater amount of radioactive phosphorus in the lower branches and leaves, during which time there exists a direct proportionality between the phosphorus content of the branches and that of the leaves located on them.

By isolated feeding of the individual roots of fruit trees, both in a garden crop of apple seedlings and in an orchard of fruit-bearing trees, it was shown that unilateral focal introduction of fertilizers in an area representing one fourth of the circumference of the trunk guarantees accumulation of phosphorus throughout the top of the fruit tree.

Among young apple trees, when part of the root system received isolated feeding, after two weeks following introduction of fertilizers, the content of the phosphorus isotope on the fertilized side was 50 to 100 times greater than the amount of it in the leaves and branches on the unfertilized side. But after only two months after fertilization, the content of P^{32} was almost the same in the entire top of the tree. This also verifies the possibility of effective utilization of fertilizer by fruit trees when focal introduction is employed.

The Ukrainian Scientific Research Institute of
Horticulture

THE NATURE OF THE DISTRIBUTION OF PHOSPHORUS ENTERING THE APPLE TREE AMONG ITS VARIOUS ORGANS

N. D. Spivakovsky

A knowledge of the regularities in the distribution of nutritive substances, phosphorus in particular, among the various organs of the fruit tree is necessary in order to work out a correct system of feeding and pruning fruit plants.

Experiments have shown that there exists among apple trees an autonomic link between individual roots and branches. The distribution of P^{32} entering a branch among the different organs and sections of the branch is extremely irregular. The seeds of the fruit contain the greatest amount of radioactive phosphorus, then the fruit-bearing rings and their leaves. The rings not bearing fruit, their leaves and the flesh of the fruits were characterized by a smaller phosphorus content.

The distribution of radioactivity among homologous organs on a skeletal branch is subject to the rule of age variability discovered by Professor N. P. Krenke. Within the limits of a single sequence of branches, there is observed an ascending activity gradient from the older organs to the younger ones.

A high phosphorus content is possessed by young organs which are formed from dormant buds on the older portions of a branch. In passing from a branch of a lower succession to a branch of a higher succession, the activity gradient of homologous organs of the same age is descending. This depends, however, on the relative strength of the branches of these successions. The activity gradient is ascending in the case of a branch of somewhat greater strength from a high succession in comparison with a branch from a lower succession. The successions of these branches apparently switch places. This evidently explains the presence of the maximum phosphorus accumulation by homologous organs of the same age in the second or third succession of branches among fruit-bearing trees.

In setting up experiments it is necessary to consider the peculiarities of the intake into fruit plants of nutritional elements as strictly dependent on the method of introducing fertilizers; this holds true also in

working out techniques of taking plant samples in order to establish the nature of the distribution of nutritive elements among the different organs and the portions of the composite top of the fruit tree.

The I. V. Muchurin Scientific Research Institute
of Pomology

THE LINK BETWEEN BRANCH ROOTS AND BRANCHES OF DIFFERENT TYPES OF TREES AND SHRUBS

Yu. A. Belavin

The aim of research, conducted in 1956, was to shed light on the manner in which phosphorus passes from one of the branches of the root system into branches at the top of trees and shrubs raised from seed, propagated by grafting, and obtained by planting green slips, i.e., plants having root systems of different origin. The method of marked atoms was employed to solve this problem, and the radioactive isotope of phosphorus, P^{32} , was used as the indicator.

The experiments were conducted from May to June of 1956. The plants used in the experiments were the apple tree, mountain ash, and lilac, both the Hungarian and the ordinary variety; grafted plants were used as well as those with their own roots. One of the secondary branches of the root systems of the plants was disengaged from the soil, and through it was introduced the isotope P^{32} ; then determination was made of the radioactivity in the leaves of branches at the top of the plant.

In the apple, mountain ash, and lilac plants cultivated from seeds and possessing their own roots, all of which had been injected through one secondary root, phosphorus was detected only in certain top branches, located on the same side of the tree or shrub as the root absorbing the fertilizer phosphorus. This indicates the presence of a link between the given root and only certain branches.

Radioactivity was detected in all the branches at the tops of the grafted trees and shrubs; this indicates a link between the secondary root of the stock which absorbed radioactive phosphorus and all the branches of the graft.

Radioactivity was detected in all of the branches at the tops of the plants raised from green slips which absorbed phosphorus through an adventitious root and of an apple tree raised from seed but absorbing phosphorus through an adventitious root. This indicates a link between adventitious roots of plants and shrubs with all the branches of the crown. An analogous link was established between secondary roots of the stock with all the branches of the graft among grafted plants.

The results of the experiments conducted, should they be verified by more ample material, point to the possibility of employing different agricultural techniques in the cultivation of trees and shrubs propagated by different methods.

The Moscow Institute of Forest Technology

THE USE OF LABELED PHOSPHORUS IN A STUDY OF NONROOT FEEDING OF FRUIT PLANTS

P. K. Ursulenko

In a study of nonroot feeding employing the method of labeled atoms, the task proposed was one of shedding light on the nature and conditions of the intake of nutritive elements when fruit plants are treated with fertilizer substances.

It was established as a result of the research that when radiophosphorus is applied to leaves it is absorbed through both upper and lower surfaces. The extent of the intake of radiophosphorus through the lower surface of a leaf is significantly greater (by ten or more times) than through the upper surface.

An increase of up to 30% in the productivity of the apple tree was attained in the experiments employing nonroot feeding of fruit plants. This increase in yield resulted from the fact that the photosynthetic energy of the leaves of the apple tree is appreciably augmented under the influence of nonroot feeding.

Field and laboratory experiments were conducted with the aim of combining nonroot fertilizers with chemical toxicants. A study was made of the extent of absorption of labeled phosphate when applied to the leaves of an apple tree in the form of superphosphate combined with an emulsion of DDT. The experiments showed that the chemical toxicant does not exert a negative influence on the extent of absorption of radiophosphorus by a leaf.

Valuable data were obtained by combining nitrogen and potassium fertilizers with Bordeaux mixture. In addition, consistent results were obtained in increasing the productivity of the apple tree with the use of urea and potassium sulfate or potassium nitrate as a nonroot fertilizer. Spraying with superphosphate in combination with Bordeaux mixture, a method recommended in the industry, was scarcely vindicated. The easily soluble salt of superphosphate, calcium phosphate, is converted into the difficultly soluble diphosphate salt or the insoluble salt, calcium triphosphate, under the influence of the calcium hydroxide of Bordeaux mixture.

The question always arises of the reasonableness of carrying out non root feedings through the leaves against a background of abundant soil alimentation. Experiments were conducted using labeled phosphate with the aim of shedding light on this problem. In a field experiment of several years duration, in which were studied fertilizer doses of 60, 120, 180, and 240 kg/hectare of the fundamental nutritive elements, nitrogen, phosphorus and potassium, labeled phosphorus was applied to the leaves of the branches of fruit trees. The data obtained did not show changes in the absorption of radiophosphorus from augmenting the fertilizer dosages, as might have been expected.

Consequently, against a background of abundant soil alimentation, the efficiency of the leaves still remained on an insufficiently high level; their potential energy was not fully realized. This was apparent from the fact that photosynthesis increased appreciably under the influence of non root alimentation. Thus, it is seen that a high level of soil nutrition, although guaranteeing increased efficiency of the leaves, is far from always effecting their maximal photosynthetic activity.

The I. V. Michurin Scientific Research Institute of
Horticulture

NONROOT ALIMENTATION AND ITS INFLUENCE ON THE INTAKE OF NUTRI- TIVE SUBSTANCES FROM THE SOIL INTO THE TEA PLANT

R. Kh. Aidinyan

Experiments were conducted under natural conditions on tea plantations of industrial importance at the "Dagomys" state tea farm of the Krasnodar region. The soils of the area were yellow earth, developed on shale and fertilized with superphosphate and ammonium sulfate in accordance with one agricultural standard.

Nonroot feeding of one branch of the central formation of the tea plant with nutritive solutions containing the radioactive isotopes P^{32} , S^{35} , and Ca^{45} showed that phosphorus, sulfur, and calcium are capable of being transferred from one branch of the tea plant into other branches. Transfer of these elements takes place both downward, in the direction of the transpiration flow, and upward, into younger organs. The indicated elements concentrate most of all in the top shoot of the tea plant. On the whole, the transfer of these elements in an ascending direction significantly exceeds transfer in a descending direction.

It was discovered that, when nonroot feeding is conducted, phosphorus and sulfur enter into individual strands of the roots of the tea plant, and excretion of the same elements takes place through them into the soil. Excretion of phosphorus and sulfur into the soil by the roots is of a local nature.

Nonroot feeding only partially fulfills the plant's requirements for the nutritive substances necessary to it. Under natural conditions the intake of nutritive substances through the leaves is in a certain measure linked with their intake through the roots, stimulating or retarding the latter.

Nonroot fertilizing of the tea plant with potassium and boron, each one separately, increases the intake into the plant of nutritive elements found in an absorbed state in soil colloids and in artificially prepared ion-exchange resins. The plant absorbs most the phosphorus and sulfur combined with ion-exchange resins. Intake into the plant of phosphorus stably combined with soil colloids is increased as a result of nonroot introduction of potassium and boron. Spraying the leaves of the tea plant with boron fertilizer increases somewhat the intake of calcium absorbed both by the colloids and by the cation-exchange resin.

Nonroot feeding should be particularly effective on those plantations where the tea plant is grown under soil conditions unfavorable for the activity of the roots, i.e., on soils having compressed alluvial layers, with carbonates present to a slight depth (about 70 to 80 cm), with a neutral reactivity, and on soils affected by processes of strongly pronounced gley formation.

The V. V. Dokuchaev Soil Institute of the Academy
of Sciences of the USSR

THE ADVANCE OF MINERAL SOLUTIONS FROM THE XYLEM INTO THE PHLOEM

N. N. Kiselev

The aim of the research was an experimental demonstration of the transfer of solutions in a horizontal direction from the xylem into the phloem via the medullary rays. The work was conducted with pruned branches of coniferous species. The branches were kept in solutions of $Na_2H^{32}PO_4$ different lengths of time, from 5 to 96 hours. The radioactive phosphorus content of the xylem and phloem was determined. The experiments showed that a solution rising through the xylem is transferred into the phloem. Phosphorus is detected even with brief

exposure. In the case of prolonged exposure up to 50 hours the phosphorus content of the phloem becomes greater than that of the xylem. Consequently, accumulation of phosphorus occurs in the phloem.

A study was made by us of the paths through which the phosphorus transfer takes place from the xylem to the phloem. Two directions are possible—the tangential, i.e., through the surrounding region, and the radial. Opposition to the movement of a solution is much less in the first instance than in the second, because of the arrangement of the bordered pits in the tracheids. Passage through the tracheids in a radial direction is practically impossible.

When the xylem was notched, in the aim of impeding the movement of phosphorus in a tangential direction, it was observed that phosphorus transfer takes place in a radial direction. In addition, phosphorus transfer was possible only through the medullary rays.

The Moscow Institute of Forest Technology

THE PHOSPHORUS FEEDING OF ARBOREAL SPECIES

D. D. Lavrinenko

On comparatively rich soils the greatest intensity of phosphorus absorption from the soil is possessed by the ash, linden, hornbeam, holly maple, oak, and birch. If the intensity of phosphorus absorption by the ash tree is taken as 100%, then, correspondingly, phosphorus absorption by the linden will be, on the average, 90 to 80%, that of the hornbeam—90 to 60%, of the holly maple—70 to 50%, of the oak—50 to 30%, and of the birch—30 to 20%.

The intensity of phosphorus absorption among arboreal species changes substantially at different periods of the growing season. These changes proceed differently among different arboreal species. In the second half of the growing season the ash, oak, linden, and hornbeam lower intensity of phosphorus absorption to a greater extent than the other species.

The presence in checkered cultivations of sections with richer and less rich soils made it possible to trace the change in intensity of the vital activity of the species being studied. It was established that the oak, linden, and hornbeam do not respond to a worsening of the soil.

Intensity of phosphorus absorption is a reliable indicator of the interaction of arboreal species in forest plantations. The ash competes successfully with the majority of the arboreal species which we studied. This was indicated by a more intensive absorption of phosphorus by the ash in mixed cultivations than in a pure crop.

The study of the vital activities of arboreal species using the method of labeled atoms substantially reinforces the possibilities of studying their ecological characteristics.

The Ukrainian Scientific Research Institute of Forestry and Forest Amelioration

PHOSPHORUS INTAKE OF YOUNG ARBOREAL PLANTS UNDER CONDITIONS OF DIFFERING NITROGEN-POTASSIUM FEEDING

S. I. Slukhai

It was shown by research that the intensity of the absorption of phosphorus by the seedlings of arboreal species depends to a large extent on the type of plant and the special features of its feeding. Certain arboreal species, for example the holly maple, silver maple, hornbeam, amur velvet, elm, and privet absorb phosphorus more energetically than the walnut, hazel nut, eucommia, smoke tree, linden, forest pear, and coniferous species. A high level of nitrogen and potassium feeding of the shoots of arboreal species exerts a negative influence on phosphorus intake. In the second half of the summer a high level of nitrogen-potassium feeding promotes intensive intake of phosphorus into the plant tissues, particularly the leaf system.

Against a background of abundant nitrogen feeding, intensive intake of phosphorus into a seedling begins from July and continues until late autumn. Under conditions of moderate nitrogen feeding, intake of phosphorus into a plant falls off toward autumn. This is explained by the differing viability of the leaf systems, which bind the phosphorus taken in. In the first half of the summer, when the roots of the seedlings are weakly developed, local introduction of fertilizers, especially into the rows together with the seeds, is extremely significant in improving the alimentation of young plants. In the second half of the summer, processes of introducing fertilizers do not exert such a substantial influence on the utilization of nutritive substances. Phosphorus is not uniformly distributed in arboreal plants. In the top part of the stem phosphorus content is one and a half times greater than in the lower part, where the gradual formation of the xylem is taking place.

The Ukrainian Scientific Research Institute of Forestry and Forest Amelioration

THE ROLE OF THE MICROORGANISMS IN THE RHIZOSPHERE IN THE ALIMENTATION OF ARBOREAL PLANTS

A. I. Akhromeiko and V. A. Shestakova

Research conducted in 1955 and 1956 in studying the role of rhizospheric microorganisms in the alimentation of arboreal plants showed that bacteria play a leading role in the exchange of nutritive substances between arboreal plants and the soil.

The fundamental aspects of the research conducted come down to the following:

1. A direct connection exists between the development of microorganisms in the rhizosphere and the excretions of the roots.
2. The excretion of even small amounts of phosphorus by ash seedlings exerts a significant positive influence on the development of bacteria in the rhizosphere.
3. The close interdependence between the higher plants and the bacteria in the rhizosphere finds expression in the presence of a daily cycle both in the quantity of root excretions and in the quantity of microorganisms.

4. The development of microorganisms in the rhizosphere is also directly dependent upon the supply of moisture to the soil.

5. The total quantity of microorganisms in the rhizosphere of the oak and holly maple growing on ordinary black earth attained maximal magnitude in May, minimal magnitude in July, and increased again in October; this corresponded with the change in soil moisture content.

The drying-off of microorganisms and physiologically active roots in July promotes the very large increase in the amount of humus and the total amount of nitrogen and phosphorus in the root zone of the soil in comparison with the amounts of these substances in May and October.

6. The bacterization of pine seeds by nitrogen-fixing bacteria had a positive effect on the growth of pine seedlings and promoted an increase in absorption of phosphorus (P^{32}) from labeled superphosphate by the seedlings.

The All-Union Scientific Research Institute of
Forestry

THE ASSIMILATION OF PHOSPHORUS BY THE SEEDLINGS OF ARBOREAL SPECIES

A. D. Tarabrin

A study was made of the absorption of phosphorus by the seedlings of arboreal species dependent upon various depths at which superphosphate was introduced in the rows during sowing. Phosphorus assimilation was determined by the radioactive phosphorus content of the leaves or needles.

Year-old oak, holly maple, and Siberian acacia seedlings assimilate phosphorus better when superphosphate is introduced at a depth of 6 to 7 cm than when it is more deeply buried (at 15 to 16 cm).

An experiment was set up to clarify the influence of superphosphate introduced into the rows (at a depth of 6 to 7 cm) on the assimilation by seedlings of the phosphorus of basic fertilizer introduced at a depth of 15 to 16 cm.

It was established that the introduction of superphosphate into the rows exerts a positive influence on the assimilation by maple seeds of phosphorus from the basic fertilizer.

It was shown in an experiment with oak seedlings that the row superphosphate has almost no influence on the assimilation of phosphorus from the basic fertilizer. This is linked with the peculiarities of the construction of the root system of the oak seedlings.

By introducing superphosphate into "interrows" 20 cm wide at various depths below two-year-old Siberian acacia, pine, common fir, and Siberian larch seedlings. It was established that the Siberian acacia assimilates phosphorus best when superphosphate is introduced at a depth of 6 to 7 cm. Common fir seedlings do not assimilate phosphorus at all, while pine and larch seedlings assimilate it very weakly. In all of the experiments the greatest quantity of phosphorus was assimilated by the seedlings at the end of June and the beginning of July.

Experiments were conducted to study the role of the mycorrhiza in the phosphorus alimentation of oak seedlings. Seedlings with and without mycorrhiza were raised by the sandy cultivation method on Pryanishnikov's mixture in glass vessels. Radioactive phosphorus in the form of $Na_2H^{32}PO_4$ was introduced directly into the vessels, while the measurement of the activity of the leaves was made directly on the living plant.

During three months time all the oak seedlings with mycorrhiza were characterized by more intensive phosphorus absorption than those without mycorrhiza. They were also characterized by better growth.

The Moscow Institute of Forest Technology

A STUDY OF THE RATE OF THE FLOW OF WATER IN ARBOREAL PLANTS

M. V. Zhuravleva

For the solution of a number of practical problems connected with forestry, the determination of the rate of water flow among various arboreal species is highly significant. With the help of radioactive isotopes we worked out a new method of determining the rate of water flow. Radioactive P^{32} , I^{131} , S^{35} and heavy water (D_2O) were utilized.

As a result of the research it was established that the rate of transfer of the different radioactive substances and of heavy water in plant tissues is practically the same. Therefore, it can be considered that the transfer of solutions of radioactive substances through a plant occurs with the flow of water; this provides a basis for judging the rate of water flow according to the rate of transfer of radioactive substances.

The use of the method of labeled atoms made it possible to establish the rate of water flow among one-year-old arboreal plants, as well as those several years old, under different environmental conditions. It was shown that the rate of flow depends upon the supply of water to a plant and the extent of development of its leaf mass. When a sufficient water supply exists, the rate of the ascending flow is determined by the intensity of transpiration. It is low (1 to 2 m/min) during the winter quiescent stage and during the summer in cold, rainy weather. Under arid conditions in the absence of available soil moisture, when the water content of the xylem of the trunk is lowered to 35-37%, the rate of the ascending flow increases significantly and exceeds 18 to 24 m/min. In addition, there is observed a dependence of the rate of flow on the moisture content of the xylem.

The rate of water transfer increases sharply from the time of foliation of the shoots. The ascending water flow passes through the sapwood portion of the xylem of plants.

The All-Union Scientific Research Institute of
Forestry

THE APPLICATION OF CERTAIN FORMS OF HEAVY WATER IN SOIL AND PHYSIOLOGICAL RESEARCH

Yu. A. Polyakov and N. S. Germogenova

For the last few years, in a laboratory of physical chemistry of the Soil Institute of the Academy of Sciences of the USSR, a series of experiments has been conducted during the course of which use was made of various forms of heavy water. In the report presented, data are adduced which concern a method for the quantitative determination of D_2O and H_2O^{18} in soils and plants and the utilization of these compounds and indicators in soil and physiological research.

The quantitative determination of D_2O and H_2O^{18} in soils and plants was effected by densimetric and interferometric methods with an accuracy, respectively, of 0.001–0.005 and 0.4–0.2 mole %.

The flotation and interferometric methods for the isotopic analysis of water proved to be especially easy when it was necessary to examine systems with small concentration of D_2O and H_2O^{18} . However, these methods require not less than 2–3 g of the water specimen for analysis; this is quite difficult to accomplish, for example, in work with sprouts. Therefore, we attempted to work out micromethods with the use of which it would be possible to limit oneself to a few milligrams of water.

There is assembled at the present time an instrument operating on the principle of the ordinary macro-flotation apparatus. A few drops of water are sufficient for deuterium (or heavy oxygen) determinations using this instrument. The accuracy of a deuterium determination with the microflotation process does not exceed 1–2 mole %; this is due to the specific difficulties encountered in purifying and separating the liquid phase from soils and plants.

In order to improve the purification and simplify the technique of separating the liquid phase from soils and plants, an instrument has been assembled which makes it possible to separate the liquid phase without changing its isotopic composition and with a very negligible content of contaminants.

Utilizing D_2O and H_2O^{18} as indicators, we set out to find the quantitative relationship between the intensity of water intake into plants and the concentration of salts in the surrounding solution.

The data gleaned from a three-year study of this question show that between the intensity of water intake into plants and the concentration of NaCl there exists a definite relationship, which, in an initial approximation, may be expressed by an equation of a parabolic curve. It is characteristic that the intake of water into plants does not cease even when the concentration of the surrounding solution attains significant magnitude (1.5 moles/liter and higher).

Heavy water was also used to study the mechanism of the intake of water into plants from soils, the moisture level of which varied from maximal hygroscopic moisture to full capacity inclusively. It turned out that the process of water intake into plants is characterized by a very smooth curve with one definite maximum, corresponding to a moisture level equivalent to the triple maximal hygroscopy (the most vigorous plant development was observed in this particular phase of the experiment).

Of particular interest was the determination of the availability to plants of that form of soil moisture which lies in a range of numerical significance to maximal hygroscopy (and below this value). In order to shed light on this question, a definite amount of soil was reduced to the absolutely dry state; then the soil was placed in an enclosed area and saturated with steam of D_2O . By regulating the vapor tension of the heavy water it was possible to obtain soils, the moisture of which varied from values close to zero to maximal hygroscopy, inclusively. Analysis of the data derived showed that heavy water is adsorbed by plants even when the initial level of moisture lies below maximal hygroscopicity.

The V. V. Dokuchaev Soil Institute of the Academy
of Sciences of the USSR

EXAMINATION BY THE ISOTOPIC METHOD OF THE PROCESSES OF TRANSFORMATION, AGING AND CRYSTALLIZATION OF THE COMPOUNDS OF ADSORBED PHOSPHATE IONS IN SOIL, CLAY, AND PEAT MOSS

S. N. Ivanov

Surface-adsorbed phosphate ions, during the period of their interaction with soil, clay, and peat moss, are transformed into chemical compounds which gradually age and crystallize.

Isotopic exchange reactions were employed in order to study the processes of transformation, aging and crystallization of the compounds of adsorbed phosphate ions in soil, clay, and peat moss.

The initial premise in the study of the given questions is the idea of a change in relative energy or stability of the bonding of the adsorbed phosphate ions in relation to the time of their interaction with the sorbent and the degree of isotopic exchange. In comparing under dynamic conditions the relative combining energy (judged by the kinetics of isotopic exchange) of only the adsorbed phosphate ions with the combining energy of the phosphate ions which reacted with sorbent, one can conduct protracted (3 to 4 months) observations of the process of transformation of the surface-adsorbed phosphate ions into chemical compounds and their aging. The extent of isotopic exchange under the static equilibrium conditions of the experiment made it possible to establish, in turn, the process of crystallization of phosphate compounds of the type $AlPO_4$, $FePO_4$, and $Ca_3(PO_4)_2$ of different composition and basicity, formed as a result of the transformation of surface-adsorbed phosphate ions and their absorption according to chemical type.

The process of transformation of surface-adsorbed phosphate ions into chemical compounds in soils depends upon their origin. According to rate and extent of the process of transformation of the compounds of adsorbed phosphate ions in soils and kaolin, these can be arranged in the following order: red earth > sod-podsol soil > kaolin > black earth.

Expressed quantitatively, the process of transformation of surface-adsorbed phosphate ions into chemical compounds after 80 to 90 days in red earth and sod-podsol soil leads to a reduction to one half of their quantity; this process takes place to a small extent in kaolin and is completely negligible in black earth.

The above indicated transformation in lowland turf depends chiefly on its content of adsorbed calcium (and magnesium), sesquioxides of iron and aluminum and their mutual relationship.

The quantitative regularities of the process of transformation were established as dependent upon the ratio $\frac{CaO}{R_2O_3}$ of the contents of the turf.

The process of aging for 80 to 90 days of the formed chemical compounds, phosphates of different basicity and composition, in the presence of the absorption of phosphate ions and as a result of the transformation of surface-adsorbed phosphate ions, both in soils and kaolin, as well as in lowland turfs, did not cause their crystallization.

The White Russian Scientific Research Institute of
Agriculture

A STUDY OF THE SORPTION CAPACITY OF ACIDIC SOILS

S. G. Rydky and K. B. Orlova

The sorption capacity of acidic soils was determined by us following neutralization of the soils with calcium carbonate in the presence of 0.1–0.05 N solution of calcium chloride. Neutralization of soil acidity proceeds rapidly under these conditions. Shaking for a half an hour is sufficient. The subsequent determination of absorption capacity is carried out in a manner analogous to that performed when soils are saturated with metallic cations. For this purpose a solution of calcium chloride containing the radioactive isotope Ca^{45} is added to the soil suspension. After the soil is shaken with the radioisotope for a half an hour, the radioactivity of the equilibrium solution is determined. The absorption capacity of the soil is calculated by the diminution of Ca^{45} in the solution.

The absorption capacity determined in this way is taken from the sum total of exchange cations and the easily neutralized (exchange) acidity. The difference between the absorption capacity and the sum total of exchange bases represents the exchange acidity, the determination of which can be utilized as a soil characteristic for liming purposes.

In determining the capacity, we did not take into account the presence of magnesium in the absorbed state. Experiments conducted by us showed that a magnesium content of up to 20% of the sum total of exchange bases does not noticeably influence the accuracy of the determination of absorption capacity.

The M. V. Lomonosov Moscow State University

AN EXPERIMENTAL APPLICATION OF THE RADIOACTIVE ISOTOPES OF COBALT AND IODINE IN SOIL AMELIORATION RESEARCH

V. A. Emelyanov

In 1956 use was made of Co^{60} in order to determine the volumetric weight of soils and the dynamics of soil moisture by radioscopes, and of I^{131} in order to study the actual rate of flow of ground waters, the coefficient of filtration, and the intensity of the capillary rise of soil moisture by the method of labeled atoms. The essence of the method of radioscopes by γ -rays consisted in the fact that the absorption of γ -rays by a substance conforms to an exponential relationship expressed in the formula $I = I_0 e^{-\mu x}$, where x (the thickness of the layer of the substance) equals $\frac{\log I - \log I_0}{0.434 \mu}$.

The radioscopes of the soil was accomplished vertically and horizontally.

The results of the determination of the reserves of soil moisture by the method of radioscopes with γ -rays, and of the volumetric weight with horizontal radioscopes agreed well with the data of thermostatic desiccation of soil specimens.

The radioisotope I^{131} , utilized as KI^{131} , according to the data of laboratory and field experiments, is absorbed to an insignificant extent by argillaceous soils and peat.

In the study of the actual rates of flow of ground waters, radioactive iodine was introduced into the ground waters through a bore or a slit, in an amount of about 10 mc. In order to determine the rate of flow according to its direction, an alignment of bores was laid, and the radioactivity in samples of their water was determined.

According to the readings of the radiometer, the distance traveled by the labeled ground water was established. The rate of the ground water flow in peat and sandy soil, determined by the method of labeled atoms, was from 3 to 9 cm/day.

The coefficient of filtration was determined by introducing a solution of radioactive iodine into a central bore at the rate of 2 mc per 10 liters of bore water and pumping out the water from the peripheral bores with a sludge pump. The pumping was continued until radioactivity appeared in the water that was pumped out. The coefficient of filtration of peat soils in our experiments varied from 0.11 to 0.80 m/day. The intensity of water transfer in the zone of the capillary border was observed by the transfer of the labeled radioiodine of the water through the wall of the bore, and amounted to 50–60 cm from the surface of the ground water after 10–11 days.

The results of the research conducted permit recommendation of the introduction of the method of radioactive isotopes and radiation into the practice of amelioration research.

The All-Union Scientific Research Institute of Hydrotechnology and Amelioration

MEASUREMENT OF SOIL MOISTURE EVAPORATION AND THE WATER RESERVE IN SNOW WITH THE HELP OF γ -RAYS

A. I. Danilin

The existing method of measuring soil moisture by the weighing and desiccation of soil samples removed with a boring bit is complex and requires the expenditure of a great deal of effort. It does not permit the continuous recording of changes in soil moisture. Methods of measurement based on the utilization of various physical and chemical soil characteristics have not been put to wide use because of a number of flaws inherent in these methods.

Since 1953, extensive laboratory and field experiments have been conducted on the measurement of soil moisture using γ -rays emitted by Co^{60} .

The determination of soil moisture utilizing γ -rays is based on measuring the extent to which the γ -rays are attenuated by the fixed soil layer. If the moisture content of the soil layer irradiated by these rays does not change, then their attenuation will be fixed. Increasing the moisture content of the soil increased the extent of attenuation of the γ -rays.

The technique worked out of measuring soil moisture is two fold—measurement of the extent of attenuation of the vertical and horizontal γ -ray beams.

During passage through the soil of the vertical γ -ray beam, moisture can be determined in soil layers of 0–20, 0–30, 0–40, and 0–50 cm. Measurement of the extent of attenuation of the horizontal γ -ray beam passing through stable soil layers 40–50 cm thick provides data on soil moisture at any level down to a depth of 150–200 cm and more.

Measurement by γ -rays has the advantage that moisture is determined not in a single spot, but in a layer, and directly in millimeters of depth of the moisture reserve. The method makes it possible, should the need arise, to trace continuously the change in soil moisture content. The results of 703 field measurements of soil moisture, carried out on the "Gigant" state farm below Moscow and in the Valdai region, using γ -rays and the thermostat-gravimetric method show that the γ -ray method is not inferior in accuracy to the

thermostat-gravimetric method and significantly alleviates the difficulties of those making the moisture observations.

In order to measure the water reserve in the fallen snow by means of γ -rays, a field snow gauge was designed, composed of a snow gauge rod, at the lower end of which was placed a vial of Co^{60} in a steel cap, while at the upper end there was a γ -quanta meter combined with a portable conversion instrument.

Preliminary testing of the snow gauge shows that the accuracy of its measurement of the water equivalent of snow is not lower than that obtained by measurement with a gravimetric snow gauge.

With the use of the γ -rays of Cs^{137} , it is possible to measure evaporation from the surface of the soil with an accuracy of 0.5–1.0 mm without weighing soil samples. Laboratory experiments which included about 100 determinations verify these considerations. The measurement of soil moisture, water reserves in the snow, and evaporation from the surface of the soil was accomplished with the help of meters of the STS-8 and STS-6 type, portable conversion apparatuses, and a gauge of the speed of computation.

The Scientific Research Institute of Hydrometeorological Instrumentation

A STUDY OF THE BIOLOGICAL FIXATION OF ATMOSPHERIC NITROGEN IN THE TUBERCLES OF LEGUMINOUS PLANTS UTILIZING THE ISOTOPE N^{15}

F. V. Turchin, Z. N. Berseneva, E. G. Plyshevskaya, and V. V. Zertsalov

In the research conducted, a study was made of the biological fixation of nitrogen in the tubercles of alfalfa, pea, and clover plants when exposed to an atmosphere rich in the isotope N^{15} . In a number of experiments nitrogen fixation was also studied in isolated alfalfa tubercles. In the course of the research, a method was worked out for the preparative separation of the bacteria from the tubercles; this made possible a detailed study of the distribution of labeled nitrogen both in individual fractions and organs of the above plants, as well as in the tubercle bacteria.

As a result of the research carried out, the following fundamental principles were established:

1. When leguminous plants are exposed to an atmosphere of N^{15} , the fixed labeled nitrogen is at first detected in large quantities only in the cell fluid of the tubercle tissue, whence it then gradually flows out into the other plant organs.

When the plants are exposed to the N^{15} atmosphere, for 6–24 hours labeled nitrogen is totally absent in the tubercle bacteria or can be detected in extremely negligible amounts, usually not exceeding the limits of possible experimental error.

Whence it follows that fixation of atmospheric nitrogen is accomplished not in the tubercle bacteria, but in the tubercle tissue, which represents degenerate tissue of the above plants. The role of the tubercle bacteria, to all appearances, consists in the fact that they induce formation of this specific tubercle tissue.

2. When the plants are exposed for a longer period of time to the N^{15} atmosphere (48–90 hours), labeled nitrogen is also detected in the composition of the nitrogen fractions of the bacteria, but its concentration in this case is always significantly lower than in the cell fluid of the tubercles or in the composition of the nitrogen fractions of all the other organs of the plants. This indicates that the fixed labeled nitrogen gets into the bacteria from the tissues of the above plants, which thus constitute the source of nitrogen nutrition for the bacteria.

3. Maximal concentration of the isotope N^{15} with any periods of exposure of the leguminous plants to the labeled nitrogen atmosphere was detected in the amide group of the asparagine contained in the cell fluid of the tubercles.

Since asparagine is formed by the reaction of ammonia with aspartic acid, it follows that one of the primary products, if not the first product, of the biological fixation of nitrogen in the tubercles of legumes is ammonia.

4. The fixation of nitrogen in tubercles isolated from plants takes place with significantly less intensity than in nonisolated tubercles, and only during the first hours after separation of tubercles from the above plant.

5. The nitrogen undergoing fixation in a tubercle continually flows out into the aboveground organs of the plants. Simultaneously with the efflux from the tubercles of the newly fixed nitrogen, there occurs also a steady influx into the tubercles of nitrogen compounds from the aboveground organs of the plants, where, on the whole, the necessary acceptors for combining the primary products of the biological fixation of atmospheric nitrogen in the tubercles are formed.

The Scientific Institute of Fertilizers, Insecticides, and Fungicides

THE INFLUENCE OF ATMOSPHERIC ELECTRICITY ON THE ASSIMILATION BY PLANTS OF THE ELEMENTS OF MINERAL NUTRITION

Z. I. Zhurbitsky

The use of labeled atoms in order to calculate the nutritive substances assimilated by plants over short intervals of time made it possible to establish the influence of the electric field of the atmosphere on the intake into plants of cations and anions from a nutritive solution.

In order to clarify the influence of the charge of an electric field on the assimilation of individual ions by plants, experiments were conducted in an artificial medium when a known charge was imparted to a metallic grid located directly above the plants, and the nutritive solution was grounded.

In the experiment with oat plants, when a negative charge of 2000 v was imparted to the grid, 78% of the P^{32} and 550% of the Ca^{45} entered the aboveground plant mass, as compared with the amounts of these substances entering the control plants, not subjected to the action of the charge. Thus, a negative charge on the grid inhibited the intake of the similarly charged phosphorus ions and strongly accelerated the intake of the oppositely charged calcium ions.

A positive charge showed the opposite effect. When a positive charge of 500 v was imparted to the grid, 133% of the P^{32} and 73% of the Ca^{45} entered the aboveground mass of the oat plant, as compared with that entering the controls. Analogous results were obtained in a number of experiments with other crops.

Experiments were conducted in the open air in such a way that the control plants were isolated from atmospheric charges by a grounded grid, while the nutritive solution of the experimental plants was grounded. Experiments conducted simultaneously with solutions containing P^{32} and Ca^{45} showed that under the influence of the electric field of the atmosphere 220% of the phosphorus and 53% of the calcium entered the aboveground organs of the oat plant, as compared with that entering the control plants. Thus, the electric field of the atmosphere, having a positive charge, stimulated intake of the negatively charged ions and inhibited intake of the positively charged ions.

The calculation of the influence of atmospheric electricity on plants makes it possible to explain a number of problems related to the mineral nutrition of plants, which hitherto have not been satisfactorily explained.

1. The entry into plants of equivalent amounts of anions and cations is not compulsory, inasmuch as there is a source of energy which secures the predominant entry of ions of one charge or the other.

2. The atmosphere, as a rule, has a positive charge with respect to the earth, and it increases with altitude; therefore, the influence of this charge is stronger on plants which have some form of antenna and attain greater height (grasses, for example) as compared with plants whose leaf apparatus is located close to the ground (for example, plants with edible roots).

To a known extent one can explain by this circumstance the different proportions of anions and cations in the composition of plants with different configurations.

3. The rapid rate of transfer of nutritive elements throughout plants, which was established in experiments with labeled atoms, becomes fully explainable, inasmuch as the phenomenon of the migration of ions under the influence of the electric potential gradient transpires with great rapidity; this should be inherent in plants, since they are permanently under the influence of an electric field.

The phenomenon of the separation by the root system of the various ions and compounds in the soil can also be explained by the influence of the charge of the electric field of the atmosphere, inasmuch as different charges can exist simultaneously in the atmosphere and since, as the most recent experiments have shown, the magnitude of the charge and even the sign of the electric field of the atmosphere are subject to significant fluctuation within short intervals of time (within an hour).

The V. V. Dokuchaev Soil Institute of the
Academy of Sciences of the USSR

THE USE OF P^{32} TO STUDY THE PHOSPHATE NUTRITION OF PLANTS AND THE ROLE OF MICROORGANISMS IN THIS PROCESS

V. V. Kotelev and A. N. Piskarev

The question of the phosphate nutrition of plants, particularly on the carbonate soils of Moldavia, which contain a great deal of free carbonates, is an extremely essential one. In order to shed light on the role of superphosphate and microorganisms in the phosphate nutrition of plants, vegetation and field experiments were set up on both the carbonate and noncarbonate black soils of Moldavia using labeled superphosphate, humus and bacterized seeds.

The following data were obtained in the vegetation experiment:

1. The utilization of fertilizer phosphorus depended upon the properties of the soil. The intake of phosphates from the soil into the plants increased on noncarbonate soil, while on carbonate soil that of fertilizer phosphates increased.

2. Increased intake of phosphorus from the soil on noncarbonate black earth corresponded to an increase in the amount of bacteria in it, which decomposed the difficultly accessible organic and inorganic phosphorus compounds.

3. The addition of humus to superphosphate on noncarbonate black earth increases the content of acid-soluble phosphatide and protein phosphorus in a plant and promotes the activity of the microorganisms in the soil.

The following facts were established in the field experiment:

1. Intake of labeled phosphorus began from the time of germination of the seeds. The addition of humus to the superphosphate retarded for a certain time the phosphate intake of the plants.

2. Bacterization of a mixture of superphosphate and humus by nitrogen-fixing bacteria promoted an increase in the mobilization of fertilizer phosphorus and also increased the quantity of nitrogen-fixing bacteria in the soil.

3. Introduction of phosphorus fertilizers during sowing significantly increased the utilization of soil phosphates by corn.

4. Bacterization of humus with nitrogen-fixing bacteria improved the utilization of the phosphorus taken into a plant and increased the protein and phosphorus content of the grain.

The Soil Institute of the Moldavian Branch
of the Academy of Sciences of the USSR

TRANSFER OF PHOSPHORUS FROM PLANTS INTO THE SOIL

D. M. Kheifets

For the last few years in the laboratory of agricultural chemistry of the Soil Institute of the Academy of Sciences of the USSR, experiments have been conducted with the aim of studying and characterizing soil located at various distances from the roots of plants with respect to its supply of the elements of plant nutrition.

For this purpose observations were made under field conditions of the distribution of phosphorus among the aboveground portions of several plants, their root systems, and the soil, using the method of labeled atoms.

When the leaves of spring wheat, corn, and sugar beet plants were subjected to nonroot treatment with labeled phosphorus, phosphorus was detected throughout the entire growing season in the roots of the plants and in the root area of the soil. This fact indicates the presence in plants of a process of phosphorus transfer, not only from the soil through the roots to the leaves, but also from the leaves through the roots to the soil. In addition, many times more phosphorus was detected in the soil of the root area than in soil outside of the root area. The portion of labeled phosphorus eliminated by the plant which remained in the soil of the root area comprised among corn plants at different stages of growth from 10 to 20%, and among the sugar beet almost 30% of the labeled phosphorus which was found at any given stage of vegetation in the plant and the soil beneath it.

The transfer of phosphorus in two opposite directions in a soil-plant system leads to accumulation of assimilated phosphates in the soil.

The V. V. Dokuchaev Soil Institute of the
Academy of Sciences of the USSR

THE QUESTION OF THE ROLE OF PRIMARY AND SECONDARY ROOTS IN THE NUTRITION OF THE CORN PLANT

I. V. Mosolov and A. V. Panova

With the aim of shedding light on the significance of the primary and secondary roots in supplying plants with nutritive substances, we conducted experiments with corn.

By using radioactive phosphorus, the accumulation of phosphorus by the different roots was traced.

An experiment was conducted by means of the isolated feeding of primary and secondary roots raised on Knop's mixture in water cultures. Radioactive phosphorus was introduced into the nutritive mixture, into the outer vessel, in a dose of 21.4 μ c per vessel. A determination of the phosphorus content was performed on the corn leaves (on a weighed portion of ash).

The results of the P^{32} determination showed that the exclusion of the primary or secondary root system from the nutritive medium leads to a sharp decrease in the phosphorus intake of a plant. This can be judged both by the intensity of radioactive phosphorus intake of a plant and by the total percentage content of P_2O_5 in the corn leaves and stalks. As a result of retarded salt intake, the growth of the corn was checked.

In the period of intensive growth of the corn, the primary and secondary roots possessed almost equal capacities for absorbing phosphorus from the nutritive solution. Secondary roots (and also aerial roots) without fine root hairs sharply decreased in ability to absorb phosphorus.

The intensity of phosphorus absorption by primary and secondary corn roots during the blossoming stage was quite different, although the plants were in identical stages of development.

The secondary roots absorbed phosphorus in greater quantities than the primary roots. As is well known, the primary root system of the corn plant to a significant extent loses its ability to absorb nutritive substances from the external environment toward the blossoming stage. On the other hand, the secondary roots, in the presence of favorable external conditions, attain their maximum development about this time.

Therefore, the alimentation of the corn plant during the blossoming period takes place, for the most part, via the secondary root system. It was noted that phosphorus intake through the secondary roots proved to be four times greater than through the primary roots.

Removal of the roots of the corn plant during the period of its intensive growth led to a cessation of growth of the vegetative mass, but did not tell on its development. The corn plant without a root system put out a plume on a par with the control plants.

The checking of the growth of the corn plant was apparently caused by the absence of those organic substances which are synthesized directly in the roots.

Consequently, the role of the root system consists not only in supplying mineral salts and water, but also in the synthesis of organic compounds necessary for normal plant growth.

The All-Union Scientific Research Institute of
Fertilizers and Agronomy

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ELECTRONIC PARAMAGNETIC RESONANCE OF RADICALS OBTAINED
FROM H_2O AND H_2O_2

S. D. Kaitmazov, A. M. Prokhorov, and A. B. Tsentsiper

The phenomenon of electronic paramagnetic resonance was applied to the study of radicals obtained from H_2O and H_2O_2 .

Comparison was made between results obtained for radicals prepared by various methods, namely:

- a) by a glow discharge;
- b) by ultraviolet irradiation;
- c) by γ -irradiation.

P. N. Lebedev Physical Institute of the
Academy of Sciences of the USSR

INITIAL STAGES OF RADIATION-INDUCED REACTIONS IN GASES

N. N. Tunitsky and S. E. Kupriyanov

1. The presence of metastable ions having a half-life of about 10^{-8} second has been established in the mass spectra of various large molecules, but the existing mass-spectroscopic methods do not permit the investigation of the kinetics of dissociation processes occurring during a period appreciably shorter than 10^{-8} second. A theoretical examination of the dissociation processes of complex molecules, which was carried out for the first time by Eyring and co-workers, shows, however, that most of the dissociation processes of activated molecular ions occur within a period of not less than 10^{-7} second.

2. In the case of large molecules, the dissociation period is probably greater than the time between two collisions in the gas (except when the pressure is very low). The primary process of the radiation-induced reaction must then be considered to be a reaction occurring at a collision between an activated molecular ion or molecule and a normal molecule.

In the case of molecules consisting of a small number of atoms, dissociation is rapid. The primary process may then be reaction between a fragmentary ion (radical) and a molecule.

3. The investigation of the mass spectra of molecules enables us to reach definite conclusions about the dissociation processes of activated particles. Comparison of the mass spectra of ordinary octane and of octane- d_8 , together with other facts, gives every reason to consider that fragmentary ions may be formed to some extent with a rearrangement of chemical bonds.

It was shown that it is highly probable that halogen is split off in the ionization of halogen derivatives of hydrocarbons.

4. As would be expected, the energy of the ionizing electrons has a considerable effect on the character of the mass spectra. It was shown that, when 100 ev electrons were used, the mass spectrum revealed a greater amount of fragmentary ions than in the case of electrons of low (30 ev) and of high (1000 ev) energies.

5. On the basis of the energy relations of the mass spectra and of experiments with "fractional" peaks it was concluded that the activation energy of the ions rises up to a certain limit as the energy of the electrons increases.

6. The mass-spectrometric method enables us to follow the initial stages of radiation-induced reactions. In the ionization of methane at low pressure with low-energy electrons we have detected ions of heavier hydrocarbons of the C-C type.

L. Ya. Karpov Physicochemical Institute of the
Ministry of the Chemical Industry of the USSR

KINETICS AND MECHANISM OF THE OXIDATION OF NITROGEN UNDER ELECTRON IMPACT

M. T. Dmitriev and S. Ya. Pshchetsky

1. The oxidation of nitrogen under the action of ionizing radiations is one of the possible effective methods of utilizing atomic energy for bringing about chemical processes. This fact, as well as the effect of this reaction on the working of nuclear reactors, demands thorough study.

Moreover, the simplicity of the original molecules makes it possible to study the relation between the primary processes in the interaction of radiation with the molecules and the mechanism and kinetics of the subsequent chemical reactions - a fundamental problem in the theory of radiation chemistry.

2. We have previously elucidated some of the reaction laws for the oxidation of nitrogen at low pressures under the action of slow electrons. It was shown that the reaction is of second order and that the rate constant is proportional to the ionization function of nitrogen. The present paper gives the results of an investigation of kinetic and other laws of this reaction proceeding under the action of 200 kev electrons; it gives also results of some measurements in an electric discharge, which were carried out with the object of further studying the reaction mechanism for electron impact.

3. The kinetics of reaction under the action of fast electrons at atmospheric pressure was investigated. The mole fraction of oxygen in the gas mixture had the values 0.2, 0.5, and 0.8.

Under these conditions the reaction rate was again in accord with a second-order equation. The rate constant for the reaction was proportional to the electron current and also to the relative thickness of the gas layer. The activation energy for the reaction (measured at low pressures) was about 7 kcal/mole.

4. The energy efficiency of the reaction depends on the composition of the gas mixture. At a mole fraction of oxygen of 0.5 it is about 2 molecules per 100 ev; in air it is about 1.3 molecules per 100 ev. These values are close to the yield of oxides of nitrogen previously found in our laboratory for the irradiation of liquid nitrogen-oxygen mixtures with fast electrons (1.5 molecules per 100 ev), but are less than the yield that we found for reaction in the gas phase at low pressures under the action of slow electrons (5-6 molecules per 100 ev).

5. It was previously shown that oxidation of nitrogen arises as a result of the ionization of molecular nitrogen by electron impact. For the further elucidation of the part played by various ions in this process, some measurements were made in an electric discharge, in which the reaction rate again follows a second-order equation.

Measurements were made in which positive or negative ions were withdrawn from the sphere of reaction onto a probe. It was shown that the removal of positive ions retards reaction, whereas the removal of negative particles accelerates reaction. The quantitative relationships observed confirm the leading part taken by the process of nitrogen ionization in the oxidation reaction.

6. The results obtained on the effect of negative particles on the reaction indicate that in reaction at atmospheric pressure a very unfavorable part is played by recombination processes occurring between oppositely charged ions. An expression is given for the dependence of the reaction-rate constant on the coefficient of recombination of ions.

L. Ya. Karpov Physicochemical Institute of the
Ministry of Chemical Industry of the USSR.

CHEMICAL ACTION OF Co^{60} γ -RADIATION ON SOLID CRYSTALLINE SALTS OF IONIC STRUCTURE (KNO_3 , KClO_3 , KClO_4)

A. S. Baberkin

This work was carried out with the object of determining the chemical effect of γ -radiation on solid crystalline salts of ionic structure (KNO_3 , KClO_3 , KClO_4) at low dosages (up to 10 million roentgens per gram of salt) and of determining also the effect of the temperature at which the irradiated salts are heated on the yields of radiolysis products.

The effect of various ionizing radiations in doses about one hundred times as great as those used in the present work has been studied for these salts by some foreign authors.

In the present work we have shown that solid potassium nitrate is decomposed under irradiation, with formation of nitrite and gaseous oxygen. At room temperature the yield of nitrite attains a value of about 0.8 molecule per 100 ev. Under these conditions most of the gas remains trapped in some form or other within the crystals.

In samples heated at 127° the yield of nitrite obtained when the irradiated salt is dissolved in water is reduced to 0.6 molecule per 100 ev. The yield of oxygen is increased very slightly. The most favorable effect on the removal of gas trapped within the crystals is observed when the irradiated salt is heated at 150° (above 129°, the crystal-transition point for potassium nitrate). In samples heated at this temperature the yield of nitrite obtained when a sample of the salt is dissolved in water falls further to 0.4 molecule per 100 ev, but the yield of gas rises to 0.2 molecule per 100 ev. The occurrence of the reverse transition of nitrite into nitrate during the heating of the irradiated salt indicates the existence of intermediate transformation products of potassium nitrate, NO_2 or NO_3 radicals, and O atoms.

The transformation products of solid potassium chlorate are chloride, oxygen, and chlorite. It was shown that heating the irradiated salt at 200° has little effect on the process of escape of gas from the crystals. In samples heated at 200°, the yield of chlorite falls to 0.8 molecule per 100 ev (in unheated samples the yield is 1.2 molecules per 100 ev). The reduction in the yield of chlorite is associated with its conversion into chloride and oxygen. In the course of irradiation the salt becomes colored, probably owing to the formation of free radicals and color centers. It is considered that the radiation-induced transformation of potassium chlorate, which has a radical mechanism, includes two possible ways of decomposition of the intermediate ClO_2 radicals: to chlorite and to chloride.

Under the action of γ -radiation, solid potassium perchlorate is reduced to chlorate. Complete removal of gas formed in the crystals during irradiation is achieved by heating the irradiated salt in a vacuum at a temperature above the crystal-transition point (299° for KClO_4).

The original chlorate yield of 1.1 molecules per 100 ev is lowered to 0.7 in samples heated above the transition point. The part of the chlorate that has disappeared is to be found in the form of chloride and oxygen. In the course of irradiation the salt becomes colored. It is considered that the primary products formed by the irradiation have radical character and are decomposed to an increasing extent as the temperature at which the salt is heated is raised.

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of Chemical Industry of the USSR

EFFECT OF KCl AND KBr CONCENTRATION ON THE YIELD OF MOLECULAR RADIOLYSIS PRODUCTS IN AQUEOUS SOLUTIONS

St. A. Brusentseva and P. I. Dolin

With the object of determining the mechanism of the formation of molecular products in the radiolysis of water, an investigation was made into the dependence of the yields of H_2 and H_2O_2 on the solute concentration in KBr and KCl solutions saturated with helium and nitrogen. In KBr solutions the accumulation of molecular bromine was also investigated. The solutions were irradiated with x-rays and Co^{60} γ -rays.

It was found that the H_2 yield does not remain constant when the concentration of the solution is increased. At first it increases, then remains constant over a certain range of concentrations, and with further increase in concentration, it again rises with simultaneous rise in the yield of free bromine. However, the yield of molecular hydrogen attributable to the reaction $\text{H}_2\text{O} \xrightarrow{\gamma} \frac{1}{2} \text{H}_2 + \frac{1}{2} \text{H}_2\text{O}_2$ falls.

Formation of H_2O_2 proceeds with constant yield over the whole range of concentrations.

Increase in G_{H_2} in dilute solutions indicates that Br^- ions have a protective effect with respect to H_2 , being able to react with radicals distributed in the mass of the solution. When most of these radicals are consumed in reaction with Br^- ions, the H_2 yield ceases to depend on concentration. The lowering of the H_2 yield in concentrated KBr solutions can be explained only on the assumption that Br^- ions react with free OH radicals and free Br with H atoms present in places of high ionization density (in dilute solutions these are consumed by conversion into molecular products). These results, therefore, confirm the radical mechanism of the formation of the molecular products of the radiolysis of water. The constant yield of H_2O_2 over the whole range of KBr concentrations may be associated with the catalytic decomposition of H_2O_2 in KBr solutions.

Molecular bromine is detected only from concentrations of 0.1 M upwards. This result confirms the view that in dilute solution the formation of atomic bromine by the reaction $\text{Br}^- + \text{OH} \rightarrow \text{Br} + \text{OH}^-$ is compensated by the reaction $\text{Br} + \text{H} \rightarrow \text{Br}^- + \text{H}^+$, as a result of which molecular bromine does not accumulate in the solution.

In more concentrated solutions, G_{Br_2} increases with increase in the electron fraction of Br^- ions. When the yield is related to the energy absorbed by Br^- ions, G_{Br_2} remains constant from concentrations of about 2 M upwards. This form of relationship indicates that, in concentrated KBr solutions, molecular bromine is formed as a result of the direct action of radiation on Br^- ions.

Unlike KBr solutions, KCl solutions show separation of H_2 at concentrations of about 0.1 M upwards. This result, and also other features of radiation-induced transformations in chloride solutions, indicates that some difficulty is met in the interaction between an OH radical and a Cl^- ion.

Institute of Physical Chemistry of the Academy of
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RADIATION-INDUCED REACTIONS IN NITRATE SOLUTIONS

N. A. Bakh, V. I. Medvedovsky, A. A. Revina, and V. D. Bitukov

1. It is known that, under the action of ionizing radiations, nitrite, hydrogen peroxide, and oxygen are formed in aqueous nitrate solutions; products of the reduction of NO_3^- to beyond the NO stage have not been detected. In order to elucidate the mechanism of the processes occurring in the system it is necessary to know the initial yields of the products and the effect of the concentration of the solution and the dosage on the relative amounts of products. Useful information is provided by observations on the changes of potential of electrodes present in the solution during the irradiation. The results now under consideration refer to the action of x-rays and to solutions saturated with nitrogen.

2. Determinations carried out on irradiated NaNO_3 solutions of increasing concentration showed that the yield of molecular hydrogen does not remain constant, but falls from $G_{\text{H}_2} = 0.5$ molecule per 100 ev at 0.1 M to $G_{\text{H}_2} = 0.05$ molecule per 100 ev at 5.5 M. This indicates that molecular hydrogen is formed from atomic hydrogen and not by an independent mechanism.

3. For the determination of the initial yields of H_2O_2 and O_2 , for which the data in the literature are unreliable, we developed a special apparatus which permitted simultaneous polarographic measurement of H_2O_2 and O_2 concentrations during irradiation for concentrations of 10^{-3} mole/cc upwards and dosages ranging from $3 \cdot 10^{18}$ ev/cc upwards. In 1 M NaNO_3 at pH 6.5 at a dosage of 10^{18} ev/cc-sec, initial yields of $G_{\text{H}_2\text{O}_2} = 2.6$ molecules per 100 ev, $G_{\text{O}_2} = 0.2$ molecule per 100 ev, and $G_{\text{NO}_2} = 3$ ions per 100 ev were obtained. With further irradiation G_{O_2} increases, evidently owing to the decomposition of H_2O_2 . With increase in dosage intensity, the yields of H_2O_2 and NO_2 fall. Both the radiational and nonradiational reactions in which H_2O_2 and NO_2 are concerned affect the yields of these species.

4. The potentials of electrodes immersed in nitrate solutions reflect changes in the oxidation-reduction state of the solutions during irradiation. On the potential determined by the relative amounts of HNO_3 and HNO_2 is superimposed an effect present during irradiation, which in the case of a Pt electrode is associated with short-lived reducing radiolysis components of the irradiated solution and, in the case of an Au electrode, with short-lived oxidizing radiolysis components. When irradiation is stopped, these effects disappear and the potentials of both of these electrodes in 1 M HNO_3 correspond to the equilibrium potential of the HNO_2 - HNO_3 system.

The effect observed at a Pt electrode becomes more marked as the NO_3^- concentration is reduced and the dosage intensity is increased. In 1 M NO_3^- it disappears when the dosage is decreased from $2 \cdot 10^{18}$ to 10^{18} ev/cc-sec.

5. The closeness of the initial yields of NO_2 and H_2O_2 , the simultaneous increase in these yields with diminution of the H_2 yield and disappearance of the hydrogen effect at a platinum electrode when the ratio $[\text{NO}_2]/[\text{H}]$ increases ([H] being determined by the dosage intensity), and the very low initial yield of O_2 all indicate that the main reactions in 1 M NaNO_3 are reduction of the NO_3^- ion by atomic hydrogen and formation of hydrogen peroxide - which later decomposes with evolution of O_2 - from OH radicals.

According to the electron fractions of NO_3^- , 5.5% of the energy of fast electrons absorbed by 1 M NaNO_3 solution are consumed in the direct interaction of the radiation with NO_3^- and may result in the formation of NO_2 with separation of an equivalent amount of O_2 , independently of the formation and decomposition of H_2O_2 . According to this mechanism, the yield of nitrite cannot exceed double the initial yield of O_2 in the irradiated system.

Institute of Physical Chemistry of the Academy of
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SOME DATA ON THE ACTION OF IONIZING RADIATIONS ON CONCENTRATED AQUEOUS SOLUTIONS OF INORGANIC SALTS

A. M. Kabakchi, V. M. Erokhin, and V. A. Gramolin

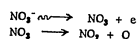
With the object of determining the main peculiarities of behavior in concentrated, as compared with dilute, aqueous solutions of inorganic salts treated with ionizing radiations, several series of experiments were carried out with nitrate and chloride solutions of concentration varying from 0.01 M to almost saturated. The solutions were irradiated with Co^{60} γ -rays, P^{32} β -rays, Pu^{239} α -rays, and products of the nuclear reaction B^{10} (n, α) Li^7 .

Irradiation of solutions of lithium, sodium, potassium, ammonium, magnesium, calcium, strontium, barium, lead, aluminum, and thorium nitrates showed that the yield of the main product of the radiation-induced reaction—the nitrite ion—is, within the limits of experimental error ($\pm 10\%$), independent of the nature of the cation, being dependent mainly on the nitrate concentration. However, in highly concentrated nitrate, and also chloride, solutions in which the cations are highly hydrated (e. g. Li^+), the yield of nitrite ion or of free chlorine is appreciably reduced and becomes approximately the same as in the solid salt. This is probably associated with the fact that, as O. Ya. Samoilov and A. F. Kapustinsky suppose, very concentrated solutions of such salts have structures analogous to those of the corresponding crystalline hydrates.

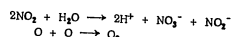
In our experiments, with increase in the concentration of the salt, the yield of nitrite ion increased appreciably. For γ -rays it was 2.5 ions per 100 ev in 0.1 M solution and 4.5 ions per 100 ev in 2 M solution. Such high yields cannot be explained solely by the action of the radiolysis products of water, H and OH. On the basis of the results of our experiments with nitrate and chloride solutions irradiated at various ionization densities, it may be supposed that nitrite ions in concentrated nitrate solutions and free chlorine in concentrated chloride solutions are formed both by the action of the radiolysis products of water and by other processes. The yields of products of radiation-induced reactions in these processes are independent of the kind of radiation and depend mainly on the concentration of the salt.

If we suppose that the yields of the radiolysis products of water do not change substantially with increase in the concentration of the salt, then it is most probable that the increase in the yields of the main products of the radiation-induced reactions (nitrite ions in nitrate solutions and free chlorine in chloride solutions) is associated with the "direct" action of radiation on the solute.

The mechanism of direct action on the nitrate ion can be represented as follows:



and further:



It is most probable that the electron ejected will be captured by a water molecule: $\text{H}_2\text{O} + e \rightarrow \text{H}_2\text{O}^- \rightarrow \text{H} + \text{OH}^-$

The H atoms formed will react with nitrate ions and increase the observed yield of NO_2^- .

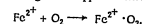
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FORMATION AND TRANSFORMATION OF IRON COMPOUNDS IN THE RADIOLYSIS OF AQUEOUS SOLUTIONS

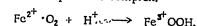
A. I. Chernova, V. D. Orekhov, and M. A. Proskurnin

The study of the behavior of ferrous iron under radiolysis conditions is of considerable interest, for it is known that ferrous ions play a sensitizing role in oxidation reactions of aqueous solutions of organic substances. According to some authors (Devhurst, Vermell, and others), in sensitization processes of this sort iron is to be assigned the passive part of an acceptor of hydrogen peroxide (or organic peroxides) formed in the course of the oxidation of the organic substance.

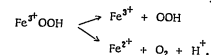
The authors of the present paper consider that it would be more correct to assign a primary role to ferrous ions and assume that, under the irradiation, unstable oxygen compounds are formed which take part in the transfer of the oxidizing component in oxidative radiolysis. It was in fact found that, in the irradiation of highly acid solutions of Mohr's salt, only part (about 16 equivalents per 100 ev) of the iron is oxidized to the ferric state; most of it (about 48 equivalents) is converted into another form, which is not determinable analytically either as ferric or as ferrous iron. In agreement with earlier suggestions (Cahill, Bray, Mansho, and others), it was suggested that in such processes a peroxide complex of iron is formed in which the iron has a higher valency, for example four. It was suggested that, in the formation of the iron-peroxide compound, an active part is taken by a ferrous iron oxygen complex which forms when solutions of Mohr's salt stand in the air, e. g. in accordance with the Georges-Philippe scheme:



The formation of such a compound is confirmed by considerable increase in ultraviolet absorption at 250 m μ in Mohr's solution that has stood in the air. The ferrous iron oxygen complex is converted by irradiation in acid solution 1 N into a peroxide complex:



This complex is unstable and slowly decomposes in two ways:



Decomposition of the iron peroxide compound in these ways results in the oxidation either of the ferrous ions themselves or of other substances present in the solution.

The direct transformation of quadrivalent iron into the trivalent condition may be effected by carrying out the radiolytic oxidation of ferrous iron in 4 N H_2SO_4 at an elevated temperature (about 80°). The same effect is achieved by the introduction of oxygen carriers, such as Ce^{3+} ions, into the irradiated solution. By the introduction of Ce^{3+} , Cu^{2+} , I^- , and Br^- ions into irradiated solutions of Mohr's salt in 4 N H_2SO_4 , we succeeded in detecting a postirradiation effect consisting in the oxidation of additional amounts of ferrous ions in the decomposition of the iron peroxide compound formed during irradiation. In certain individual cases it was found possible to raise the yield of completely oxidized iron ions (generally 60 equivalents per 100 ev) to 90 equivalents per 100 ev.

It was shown that the complex formed was able to oxidize organic compounds (e. g. formic acid), and it was suggested that the carrier of the oxidative component under the conditions of many processes in which iron takes part—both in radiation chemistry and in homogeneous catalysis—is a peroxide complex of iron of this sort. We may be sure that the study of peroxide compounds of iron will be found useful in all cases when iron is encountered as an oxygen carrier in radiation chemistry, homogeneous catalysis, and biological systems.

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ACTION OF ACCELERATED ELECTRONS ON KMnO_4 SOLUTIONS

B. A. Gvozdev and V. N. Shubin

There is very little information in the literature on the action of ionizing radiation on KMnO_4 solutions. This paper describes an investigation of the reduction of potassium permanganate solutions under the action of a beam of accelerated electrons.

1. Reaction yields were determined for the reduction of KMnO_4 in the concentration range from 10^{-2} to $3 \cdot 10^{-4}$ M for various values of the initial pH of the solution.
2. The effect of the acidity of the solution on the rate of the reduction reaction was determined in the pH range 0.4-12. There is a maximum yield at pH 2.05.
3. It was shown that the yield is independent of the mean dosage intensity in the range 10^{17} - 10^{19} eV/sec.
4. A possible mechanism was proposed for the reduction of potassium permanganate in aqueous solution under the action of radiation.

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ACTION OF γ -RADIATION ON COLLOIDAL SOLUTIONS OF COBALT, NICKEL, SILVER, AND GOLD SULFIDES

E. M. Nanobashvili and L. P. Beruchashvili

1. Under the action of Co^{60} γ -radiation sols of cobalt, nickel, silver and gold sulfides undergo far-reaching changes until complete solution or coagulation occurs.
2. The loss of stability of sols of cobalt, nickel, silver, and gold sulfides under the action of radiation is due to secondary reactions between the sol-stabilizing HS^- and S^{2-} ions and OH radicals or hydrogen peroxide molecules formed in the intermicellar liquid of the irradiated sols.
3. The gels formed from CoS and Ag_2S under the action of radiation differ greatly in structure from the gels formed by the action of electrolytes.
4. The passage of colloidal solutions of metal sulfides into true solution under the action of radiation may find practical application in the technology of enriching sulfide ores containing rare elements in a diffusely scattered form.

P. G. Melikishvili Institute of Chemistry of the Academy of Sciences of the Georgian SSR, Tbilisi

SIMULTANEOUS POLAROGRAPHIC DETERMINATION OF H_2O_2 AND O_2 IN NITRATE SOLUTION DURING THEIR IRRADIATION

V. I. Medvedovsky

1. The previously used procedure, whereby hydrogen peroxide and oxygen are determined after the irradiation, gives incorrect values for their initial yields because they react with other radiolysis products or undergo catalytic decomposition.
2. A procedure is developed for the simultaneous polarographic determination of hydrogen peroxide and oxygen during the irradiation. The method is based on the use of two dropping mercury electrodes in one cell containing a common anode. With the aid of two independent electric circuits and a photoregistering system, the two simultaneous radiation-induced processes are recorded on one diagram.
3. From the resulting curves initial yields of hydrogen peroxide and molecular oxygen are found for various dosage intensities. It is shown that at low dosage the yield of molecular oxygen is of the order of one-tenth of the yield of hydrogen peroxide.

Increase in dosage intensity results in reduction in the yield of hydrogen peroxide with simultaneous increase in the yield of molecular oxygen.

On the basis of the results, inferences are made concerning the most probable mechanism of the formation of hydrogen peroxide and molecular oxygen in 1M NaNO_3 .

Institute of Physical Chemistry of the Academy of Sciences of the USSR

KINETICS OF THE DECOMPOSITION OF HYDROGEN PEROXIDE UNDER THE ACTION OF γ -RADIATION

V. Ya. Chernykh, S. Ya. Pshezhetsky, and G. S. Tyurikov

1. The kinetics of the decomposition of hydrogen peroxide in aqueous solutions under the action of ionizing radiations have been investigated by various workers. However, the resulting data on the dependence of reaction rate on H_2O_2 concentration and irradiation intensity, and on reaction yields as related to absorbed radiation energy are in many ways contradictory, which is probably largely attributable to the fact that the measurements were carried out in limited concentration ranges in dilute solutions.
 2. We investigated the kinetics of the decomposition of H_2O_2 in aqueous solutions over a wide concentration range - from 2 to 92 mole % of H_2O_2 - reaction being promoted by γ -radiation. We studied also some of the kinetic laws of the thermal and photochemical reactions in the same concentration range.
 3. It was shown that the rate of the radiational reaction, expressed as a function of the H_2O_2 concentration, passes through a maximum, which occurs at about 35-40 mole % of H_2O_2 . The reaction rate is proportional to the square root of the radiation intensity at all concentrations investigated.
- The intensity of the γ -radiation was varied from $0.26 \cdot 10^{18}$ to $1.84 \cdot 10^{18}$ eV/liter-sec; the temperature was varied from -30° to 50° .
- The dependence of the reaction rate on temperature was investigated at 50, 30, 10, 1, -4 , -11 , and -21° .

For all solutions there is a linear relationship between the logarithm of the reaction rate and the reciprocal of the temperature.

The straight line has a break at about 10° . In the temperature range from -21° to 10° the mean activation energy is 6.5 ± 1.0 kcal/mole; above 10° the mean activation energy is 2.8 ± 1.0 kcal/mole. This is caused by superposition on the rate of the diffusion reaction.

4. Reaction yields, expressed with respect to absorbed γ -radiation energy, depend on concentration and temperature and lie between the limits of 21 (at -4°) and 230 (at 50°) molecules of decomposed peroxide per 100 ev. Such yields are characteristic of a chain process.

5. Thermal reaction rates were measured in the same concentration range at 10, 30, and 50° . The relation of reaction rate to H_2O_2 concentration has the same character as for the action of γ -radiation.

In absolute value the rate of thermal decomposition at $30-50^\circ$ is approximately one-tenth of the rate of radiational decomposition.

The mean activation energy of the thermal reaction is 12.6 ± 1.5 kcal/mole.

6. The concentrational dependence of the rate of reaction in presence of ultraviolet radiation was investigated over the same range of H_2O_2 concentrations. The character of the relationship is the same as in the previous cases. The straight line, $\log W$ against $1/T$, has a break in the region of 10° .

In the range $1-10^\circ$ the activation energy is 7.3 kcal/mole, and in the range $10-50^\circ$ it is 4.0 ± 1.0 kcal/mole. This effect is again due to the superposition of diffusion.

7. The identical characters of the relationships of reaction rate to concentration, irrespective of the way in which reaction is initiated (by radiation, photochemically or thermally) and the closeness of the values of the activation energy in radiational and photochemical decomposition indicate that the basic mechanism of the reaction does not depend on the character of the initiation. This is due to the fact that decomposition of hydrogen peroxide is a chain process.

8. The relation between rate of decomposition of H_2O_2 and concentration is analogous to the relation between the specific conductivity of peroxide solutions and concentration. This symbatic relationship indicates that ions play an important part in the decomposition of hydrogen peroxide.

9. The kinetic laws established for radiational decomposition can be explained with the aid of the concept of the dissociation of the HO_2 radical into H^+ and O_2^- ions, which has been used previously in work on the photodecomposition of H_2O_2 . The rate equation for the reaction derived on this basis provides a satisfactory description of the experimental data on radiational, photochemical, and thermal decomposition.

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RADIATION-INDUCED OXIDATION OF SOLUTIONS OF QUADRIVALENT URANIUM

V. G. Firsov and B. V. Ershler

1. An investigation was made into the oxidation of aqueous solutions of quadrivalent uranium under the action of γ -radiation from a cobalt source. The investigation covered a wide range of concentrations both of quadrivalent and also of hexavalent uranium, and other conditions were also varied over a wide range.

2. It was shown that the following reactions occur in the radiation-induced oxidation of quadrivalent uranium:

- reaction of U (IV) with the OH radical;
- reaction of U (IV) with H_2O_2 ;
- reaction of U (VI) with the H atom;
- reaction of combination of radicals with one another.

3. The most favorable conditions for these various reactions were discussed.

4. The kinetics of the various reactions were compared, and the directions in which these investigations can be further developed and extended to other, analogous systems were indicated.

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MECHANISM OF THE ESTABLISHMENT OF A STATIONARY POTENTIAL DIFFERENCE IN THE SYSTEM Pt / AQUEOUS SOLUTION / Au UNDER THE ACTION OF γ -RADIATION

Ts. I. Zalkind, V. I. Veselovsky, and G. Z. Gochaliev

1. The study of the action of nuclear radiations on electrochemical systems undoubtedly presents scientific and practical interest. It enables us not only to make a deeper investigation of electrochemical and radiation-induced processes, but also to approach the solution of problems concerning the transformation of the energy of nuclear radiations into electrical energy.

2. As a result of an investigation into the action of γ -radiation on the system Pt / aqueous solution of acid or alkali not containing oxygen / Au, it was shown that in the irradiation of this system a stationary potential difference of about 0.9 v is established between the platinum and gold electrodes. The potential of the platinum electrode takes up a value close to that of the reversible hydrogen electrode and the potential of the gold electrode is more positive by about 0.95 v.

3. The time-dependence of the potentials of the platinum and gold electrodes and of the depolarization currents at constant potential in the course of irradiation, and after irradiation, was investigated. It was shown that the electrochemically active components of the solution are mainly the short-lived radiolysis products - hydrogen atoms and hydroxyl radicals responsible for processes proceeding respectively at the platinum and at the gold electrode. Results obtained when the solutions were saturated with oxygen in order to bind H atoms and with addition of oxalic acid, which reacts with OH radicals, confirm this conclusion.

4. The results enable us to conclude that the stationary potential difference established between the Pt and Au electrodes is associated with a difference in the electrochemical properties of these electrodes. On the basis of an analysis of polarization curves determined with still and rotating electrodes during irradiation it was established that, under given irradiation conditions (dosage $2 \cdot 10^{18}$ ev/cc), the limiting stage of processes occurring at the platinum electrode is the diffusion of hydrogen to the electrode, whereas at the gold electrode the limiting stage is the electrochemical discharge of hydroxyl radicals.

5. The electrochemical system Pt / aqueous solution / Au under γ -radiation can be regarded as a very simple radiational galvanic element operating on the basis of the electrochemical reaction of the formation of water from the radiolysis products formed by the action of γ -radiation on aqueous solutions.

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RADIATIONAL-ELECTROCHEMICAL PROCESSES IN AQUEOUS SOLUTIONS OF URANIUM SALTS

N. B. Miller, Ts. I. Zalkind, and V. I. Veselovsky

It may be expected that, when radioactive radiations act on aqueous solutions of uranium salts, changes will occur in the electrochemical parameters of the system as a result of the shift in oxidation-reduction equilibria due to reaction between primary radiolysis products (H atoms, hydroxyl radicals) and the solute. Electrochemically active oxidizing and reducing components will appear in the solution and will act on the electrodes, where they will bring about electrochemical processes corresponding to the changed parameters of the system.

Investigation of radiational-electrochemical processes in solutions of uranyl salts is of considerable interest, since their realization can occur under suitable conditions (neutron field) as a result of the liberation of energy by fission of the uranium.

1. An investigation was made into the action of radioactive radiations (of radon and of Co^{60}) on uranyl sulfate and perchlorate solutions and into the action of γ -radiation (Co^{60}) on solutions of U^{III} and U^{IV} in hydrochloric acid. It was shown that, when radioactive radiations act on salts of hexavalent uranium, uranyl ions are reduced to quinquivalent uranium ions, and as these accumulate, reactions in which these ions undergo disproportionation and oxidation by radiolysis products become important. After prolonged action of Ra radiation, the main radiolysis products are hydrogen peroxide or — in solutions of low acidity (0.1 N) — a uranium peroxide compound which appears as a precipitate. As a result of the facile oxidation-reduction transformations in the $\text{U}^{\text{VI}}/\text{U}^{\text{V}}$ system, increase in uranyl ion concentration in the solution leads to reduction in the amount of hydrogen peroxide or uranium peroxide compounds formed and to reduction in the yield in the oxidation of quadrivalent uranium. When radiation acts on $\text{U}^{\text{III}}/\text{U}^{\text{IV}}$ and $\text{U}^{\text{IV}}/\text{U}^{\text{VI}}$, there is a shift of equilibrium in the system with formation of the more highly oxidized form.

2. An analogous investigation of the effect of optical irradiation showed that the products of the photochemical reaction are quinquivalent and quadrivalent uranium salts formed by the reduction of uranyl ions, and also oxidation products, which may be hydrogen peroxide and uranium peroxide compounds. The concentration of these products depends on the relative rates of the coupled oxidation-reduction reactions occurring in the solution. In their turn, the reaction rates depend on the acidity of the solution, the nature of the anion, and the presence in the solution of oxygen or of organic additives. Optical irradiation of uranium (U^{III}) chloride solutions accelerates oxidation to the quadrivalent state.

3. It was shown that γ -irradiation (Co^{60}) of uranyl perchlorate and sulfate solutions results in the establishment of a stationary potential, in the neighborhood of the hydrogen zero, on a Pt electrode as a result of the formation of quinquivalent uranium in nonequilibrium concentrations. The value of the stationary potential depends on the acidity of the solution and the nature of the anion.

Under certain conditions a stationary potential is established at a gold electrode on account of the consumption of oxidizing radiolysis components of aqueous uranyl salt solutions; this potential has the value of 1.1 against a hydrogen electrode in the same solution.

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RADIATIONAL-GALVANIC ELEMENT BASED ON THE OXIDATION-REDUCTION REACTION $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+}$

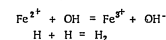
P. I. Dolin and V. I. Duzhenkov

The possibility of using the oxidizing and reducing products of the radiolysis of water in radiational-electrochemical reactions was first pointed out by V. I. Veselovsky.

In the system we have examined, the oxidizing radiolysis products of water, OH and H_2O_2 , were applied in the oxidation of Fe^{2+} to Fe^{3+} , and the reducing products H and H_2 were liberated in the form of molecular hydrogen.

The electrochemical system consisted of two half-elements: an electrode in the oxidation-reduction system $\text{Fe}^{2+}/\text{Fe}^{3+}$ in 3 N H_2SO_4 and an electrode in 3 N H_2SO_4 working as a hydrogen electrode. The electrodes were of platinum. The half-elements were separated by a diaphragm.

The consumption of Fe^{2+} in the electrode reaction $\text{Fe}^{2+} + e = \text{Fe}^{3+}$ at the positive electrode and of H_2 in the reaction $\text{H}_2 = 2\text{H} + 2e$ at the negative electrode was balanced in presence of γ -radiation mainly by the following radiational reactions:



For the stationary working of the element it is essential to have a diaphragm that passes H^+ ions, but stops iron ions.

The curves for the time-dependence of the current and potential of the element show an increase in EMF at the beginning of the irradiation until a stationary value is attained.

The coefficient of utilization of radiation energy in this system, which, as compared with others, gives a fairly high yield (8 molecules per 100 ev), is about 8%.

In order to increase this coefficient it is necessary to find a way of raising the yield in the reaction of oxidation of Fe^{2+} to Fe^{3+} in a solution saturated with hydrogen. In the meantime, the element described can be regarded only as an attempt to prove the possibility in principle of applying radiation-induced reactions in aqueous solutions to the transformation of radiation energy into electrical energy.

Institute of Physical Chemistry of the Academy of Sciences of the USSR

CORROSION BEHAVIOR OF METALS IN γ -IRRADIATED H_2SO_4 SOLUTIONS

Ya. M. Kolotyrkin, N. Ya. Bune, and G. S. Tyurikov

1. In accordance with its polarization region, a metal can be in one of three possible states: active, passive, and ultrapassive. However, irrespective of its state, the rate of dissolution of the metal in a solution of given composition is a simple function of the potential.

2. The change in the rate of corrosion of a metal under γ -irradiation is associated with the change in potential to be observed. Knowing the relation of the rate of dissolution to the potential, we may estimate — without making any direct measurements — the rate of corrosion of the metal in the irradiated solution from the value of its stationary potential.

3. The potential of a metal in an irradiated solution is determined by the kinetics of the oxidation-reduction reactions of the radiolysis components of water (H and OH) or the products of their recombination (H_2 , O_2 and H_2O_2) at a metallic surface (cf. the usual irreversible oxidation-reduction systems).

In accordance with the laws of electrochemical kinetics, the stationary potential of a noble metal in an irradiated solution not containing extraneous oxidizing or reducing agents should depend not only on the character of the reactions indicated and on the composition of the solution, but also on the nature of the metal. For an electronegative metal the value of the stationary potential in such solutions depends also on the rate of its dissolution.

4. The character of the effect of γ -radiations on the corrosion behavior of a metal is greatly dependent on its ability to undergo passivation. For metals that can be readily rendered passive, the oxidizing radiolysis component is very effective, its action being equivalent to that of an anodic current. If the rate of reduction of the oxidizing component exceeds the current density necessary for the passivation of the electrode, then the metal may be changed from the active to the passive state under the action of the radiation, a change that should be accompanied by reduction in the rate of corrosion. Similar effects are observed for certain iron alloys.

If the rate of reduction of the oxidizing component does not exceed the passivation current, as is found in the case of nickel, irradiation causes an increase in the rate of dissolution and is not accompanied by an appreciable change of potential.

5. When ions of variable valence are present in the solution, the effectiveness of the oxidizing component of radiolysis may be increased and the transition of the metal from the active to the passive condition may be accelerated.

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EFFECT OF ACCELERATED ELECTRONS ON THE CORROSION OF IRON, STAINLESS STEEL, AND ALUMINUM IN SODIUM CHLORIDE SOLUTIONS

M. N. Fokin, T. V. Matveeva, N. D. Tomashov, A. V. Byalobzhesky,
V. D. Valkov

1. An examination was made of various aspects of the effect of accelerated electrons on corrosion and electrochemical behavior in the system metal / natural oxide film / electrolyte. It was established that an important factor in these processes is the action - previously not taken into account - of electrons on the electrode, the originally fast electrons being slowed down to thermal speeds by passage through the system metal/solution, when they are able to polarize the irradiated electrode anodically or cathodically.

The results are given of corrosion and electrochemical investigations on Armco iron, 1Kh18N9T and aluminum in a flowing 0.5 M NaCl solution irradiated with accelerated electrons at a dosage intensity in the electrolyte layer adjacent to the metal of $6.6 \cdot 10^{19}$ ev/cc-sec. The samples became anodically polarized as a result of the electronic irradiation.

2. It was shown that the anodically polarizing action of electron beams on the corrosion of 1Kh18N9T steel in a NaCl solution predominates over other radiation effects, but is not the only one.

3. Distinct differences were noted in the corrosion behavior of irradiated samples of aluminum according to whether they act as an anode, as a cathode, or are unpolarized. It was found that on unpolarized aluminum there was formed a protective oxide film that is to be associated with the action of powerful oxidants - the radiolysis products of water.

4. It was shown that there is an appreciable increase in the rate of corrosion of samples of iron irradiated in sodium chloride solutions of various concentrations, which is to be explained mainly as the result of the facilitation of the cathode process together with the depolarizing action of short-lived radiolysis products of water.

5. It was shown that with increase in the irradiation intensity beyond a certain definite value, the rate of corrosion of 1Kh18N9T steel in 0.5 M NaCl increases more rapidly than the electronic current density. This is to be explained by the interaction of two processes:

- formation of supplementary local anodes on the sample in association with change in the electrode surface during its absorption of the energy of the electronic irradiation, and
- healing of disrupted patches of the surface by the frontal mechanism (growth of a protective film).

6. It was shown that the corrosion effects observed in these experiments did not result from the thermal effect of the radiation.

7. Investigations were made into several ways of protecting 1Kh18N9T steels irradiated with fast electrons in 0.5 M NaCl from corrosion, and it was shown that it is possible to use the methods of

- cathodic protection and the protector-block method, and
- introduction into the electrolyte of reducing agents that are oxidized at more highly negative potentials than the potential for the anodic destruction of the passive state of the steel.

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CHANGE IN THE ELECTROCHEMICAL ACTIVITY OF METALS UNDER THE ACTION OF RADIATION

I. L. Rozenfeld and E. K. Oshe

1. In the irradiation of galvanic elements (Zr-Al, Zr-Fe, Fe-Al) in a moving electrolyte (3% NaCl) by a beam of fast (0.8 Mev) electrons at an intensity of $15 \mu\text{A}$ per sq. cm, a sharp rise in the current of the element is observed. When irradiation is discontinued, the current falls sharply to its initial value. Experiments in which only the anode or cathode was irradiated showed that an increase in current is observed only when the cathode is irradiated, the effect not being observed when only the anode is irradiated. Under irradiation, the anodes underwent considerably more destruction than they did under the same conditions but in absence of radiation.

2. The observed effect cannot be explained by the factors previously considered to be the main causes of the acceleration of electrode reactions by radiation (rise in temperature due to absorption of radiation energy, formation of radiolysis products, anodic polarization due to charged particles).

3. The change in the electrochemical activity of metals under irradiation is to be associated with the accompanying changes in the physical properties of oxide films on metals, which are regarded as semiconductors. If we take account of the fact that the current of the elements is determined by the rate of the cathode reaction of reduction of oxygen, and assume that the latter is limited by the high resistance of the semiconducting film on the cathode, then radiation capable of causing "radiational conductivity" in this film should accelerate the cathode reaction and lead to a sharp increase in the current of the element. On the basis of this proposed mechanism, irradiation of the anode cannot lead to increase in the current of the element, which is confirmed by experiment.

4. The relation of the current of the element to the radiation intensity was studied theoretically and experimentally. From the theoretical examination, which was based on concepts of the photoconductivity of semiconductors, the following relationship was derived:

$$J_k = J_k^0 + A\sqrt{I}$$

in which J_k^0 is the current of the element in absence of radiation;

I is the radiation intensity; and

A is the constant for the given galvanic element.

The calculations made agreed satisfactorily with the experimental results.

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RADIATIONAL SENSITIZATION BY MEANS OF OXIDE SEMICONDUCTORS IN REACTIONS OF FORMATION AND DECOMPOSITION OF HYDROGEN PEROXIDE IN AQUEOUS SOLUTIONS UNDER THE ACTION OF γ -RADIATION

D. M. Shub, G. S. Tyurikov, and V. I. Veselovsky

The ability of oxide semiconductors to sensitize chemical reactions in presence of radiation may be of great importance for the development of effective means of utilizing the energy of nuclear radiation for chemical purposes.

In this connection we carried out an investigation of the heterogeneous reaction of forming hydrogen peroxide in aqueous suspensions of a semiconductor (ZnO , Al_2O_3) under the action of Co^{60} γ -radiation in presence of oxygen. We studied also the effect of suspensions of oxide semiconductors on the decomposition of hydrogen peroxide in aqueous solutions of various concentrations in the temperature range 8-45°. In presence of the suspension, increase in the rate of accumulation of hydrogen peroxide was observed in the one case, and decrease in the rate of decomposition was observed in the other. Simultaneously we investigated the laws governing the action on these systems of optical radiation that is absorbed by the oxide semiconductor. We again observed similar reactions of formation and decomposition of hydrogen peroxide, these being brought about by the transfer of the electronic-excitation energy of the semiconductor to components of the reaction medium.

The experimental results permit us to conclude that, as in photosensitized reactions in which energy of optical frequencies absorbed by the semiconductor lead to photoelectrochemical reactions, in the reactions studied radiational heterogeneous sensitization occurs and brings about analogous reactions. In the field of ionizing radiations, oxide semiconductors are most effective in transforming absorbed quanta of high energy into the energy of electronic excitation, i.e. several electron volts, sufficient for transfer of an electron into the conductivity zone. As a result, the radiation-induced reactions under consideration are brought about very effectively in the reaction zone, i.e. the semiconductor-solution interface.

For this treatment great importance must be attached to comparison of the sensitizing activity of semiconductors with their fluorescence properties, particularly with the quenching of fluorescence by individual components of the reaction medium (O_2 and H_2O_2). The existence of a definite relationship between these properties, or of a parallelism in their variation may be regarded as evidence of the correctness of the views that we have expressed to the effect that these radiation-induced reactions that are promoted by oxide

semiconductors are dependent on transfer of electronic-excitation energy of the semiconductors to components of the reactive medium.

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OXIDATION OF AQUEOUS SOLUTIONS OF BENZENE UNDER THE ACTION OF HIGH-POWER γ -RADIATION

E. V. Bareiko, L. I. Kartasheva, P. D. Novikov, and M. A. Proskurnin

It was shown that ferrous ions have a sensitizing action for the oxidation of benzene and other aromatic compounds. At an irradiation intensity of 20-50 roentgens per second, sensitization in this way made it possible to triple the yield of phenol, as compared with the yield in the usual process. Apart from the increase in the yield of phenol, the introduction of an iron salt completely prevents the formation of stable emulsions, which, in Weiss's opinion, are formed by biphenyl. The prevention of biphenyl formation constitutes a substantial practical improvement in the process. However, this effect remains incomprehensible from the point of view of previous concepts of the mechanism of the reaction.

Experiments with larger apparatus enabled us to obtain sufficient material for investigation, and analysis showed that the product described by several authors as biphenyl is a more complex hydroxy derivative of this compound. This is in accord with primary formation of C_6H_5OH and C_6H_5H and subsequent reaction between these or polymerization with benzene molecules. Weiss's scheme does not provide an explanation of the absence of biphenyl among the reaction products, the primary intermediary being regarded as the phenyl radical ($C_6H_5\cdot$).

It was somewhat unexpected to find that a comparatively small increase in the dosage intensity (by a factor of 5-7 to about 200 roentgens per second) brings about a substantial change in the course of the process.

It was shown that, although there is an over-all increase in the yield of oxidation products, at higher irradiation intensities the yield of phenol falls and oxidation proceeds further. We investigated methods of interfering in the course of the process with the object of increasing yields and directing the process in the required direction, and these may be useful for the development of a technical scheme for the utilization of nuclear radiations.

In order to determine the nature of the sensitizing action of ferrous ions in the radiolytic oxidation of benzene in water, we carried out experiments on the photochemical oxidation of benzene under analogous conditions. These showed that benzene is oxidized in presence of water with formation of phenol and demonstrated the sensitization of photochemical reactions by ferrous ions.

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4. The relation of the current of the element to the radiation intensity was studied theoretically and experimentally. From the theoretical examination, which was based on concepts of the photoconductivity of semiconductors, the following relationship was derived:

$$I_k = I_k^0 + A\sqrt{I}$$

in which I_k^0 is the current of the element in absence of radiation;

I is the radiation intensity, and

A is the constant for the given galvanic element.

The calculations made agreed satisfactorily with the experimental results.

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ACTION OF X-RAYS ON DILUTE AQUEOUS SOLUTIONS OF SOME ORGANIC SUBSTANCES

V. I. Duzhenkov and P. I. Dolin

In order to determine the reactivities of certain organic substances toward H, OH, and HO₂ radicals, an investigation was made into the effect of additions of various organic compounds on the yield of the molecular radiolysis products of water in solutions varying in acidity.

The introduction of organic additives results in an increase in G_{H₂} and G_{H₂O₂} an effect that is more notable in acid solutions (0.1 M H₂SO₄) than in alkaline solutions. The increase in G_{H₂} and G_{H₂O₂} on addition of certain organic substances is due to the more effective interaction of the radical radiolysis products (OH and H) with the organic additive than with the molecular radiolysis products. This results in the suppression of reverse reactions and so to increase in the yields of H₂ and H₂O₂.

Different organic additions produce different effects owing to the differing reactivities of these substances toward OH, and H, and HO₂ radicals.

It was found that there is a lowering effect on the limiting pressure of H₂ in solutions saturated with O₂ when certain organic substances are added, the effect being dependent on the nature and concentration of the organic addition. It is characteristic that the greatest lowering of limiting pressure occurs in solutions of substances that increase G_{H₂} and G_{H₂O₂}.

It was shown that the lowering of limiting pressure and the increase in the initial yield of H₂ due to the addition of organic substances to aqueous solutions, are in accord with the ability of the organic substances themselves to undergo oxidative radiolysis in the pure state.

On the basis of our results, the organic substances investigated can be placed in the following order with respect to increase in the effectiveness of their interaction with the radiolysis products of water: benzene, acetic acid, heptane, acetone, ethanol, hexanoic acid, and hexyl alcohol.

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LINKED OXIDATION-REDUCTION PROCESSES IN THE RADIOLYSIS OF AQUEOUS SOLUTIONS

V. D. Orekov, M. A. Proskurnin, V. A. Sharpaty, and A. A. Zansokhova

The System Leuco Compound of Dye—Sodium Nitrate

The conversion of leuco compounds of dyes into the colored (quinonoid) forms on radiolysis in aqueous solutions proceeds in two stages (the intermediate oxidation product is a semiquinone, which, on accumulating in the solution may be reduced back by H atoms formed by the radiolysis of water).

The initial yield in the process of oxidizing the leuco compound of a dye in aqueous solution is much lower than the yield of the radiolysis products of water, OH radicals and H atoms. For example, in the oxidation of indigosol A, the leuco compound of a dye, dissolved in water, at pH 3, the yield is about 0.5 molecule per 100 ev. Introduction into the solution of an acceptor substance for the radiolysis products of water, which have reducing properties, results in a sharp rise in the yield in the oxidation reaction of the

leuco compound. Dissolved O₂ (air) can serve as one such acceptor, and in its presence the initial yield of the process is 1.4 molecules per 100 ev. The nitrate ion is still more highly effective. At appreciable nitrate concentrations (10⁻³ M to 1 M) the yield in the oxidation of the leuco compound increases to 5 molecules per 100 ev (in absence of air). This behavior is probably associated with the participation of activated water molecules (up to 12 molecules per 100 ev) in secondary processes.

The same linked processes carried out in presence of air are complicated by oxidation processes in which molecular O₂ takes part, the carrier for this being probably products of the reduction of nitrite formed in the radiolysis. Analogous processes are observed in leuco compounds of other dyes of the same type (Bromindigosol, Indigosol red brown, etc.).

The System Sodium Nitrate—Glycerol

An investigation was carried out into the conditions for the sensitization of the radiolytic transformation of sodium nitrate at various concentrations in alkaline solution (in which the rate of oxidation of nitrite formed during irradiation is reduced to a minimum). The yield in the transformation of nitrate depends greatly on the nature of the dissolved gas (for example, molecular oxygen has an inhibiting effect on the reduction of nitrate). An investigation was made into the temperature-dependence of the radiolytic transformation of sodium nitrate in the temperature range 20–90° in presence and in absence of glycerol, which sensitizes the reduction of the nitrate ion (the sensitizing effect of glycerol is notable at concentrations of greater than 5·10⁻⁴ M). In the irradiation of a solution of NaNO₂ (1M) and KOH (1M), rise in temperature from 20 to 40° causes an increase in yield of nitrite ion from 3 to 6.5 equivalents per 100 ev, and at 80–90° the sodium nitrite yield is 8 equivalents per 100 ev. Under these conditions of irradiation the introduction of glycerol in the temperature range 25–35° results in a considerable fall in the nitrite yield (to 1 equivalent per 100 ev), and at temperatures above 35°, to a rapid rise (to 10.5 equivalents per 100 ev). In the irradiation of solutions saturated with nitrogen the yield of NO₂⁻ is independent of the temperature of the solution.

Our results are of interest as an example of the sensitization of nonchain radiation-induced process in aqueous solutions, and they illustrate the hypothesis previously advanced by the authors concerning the possibility of bringing all radiolyzed water molecules into reaction under certain conditions.

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INVESTIGATION OF THE FADING OF AN AQUEOUS SOLUTION OF METHYLENE BLUE UNDER THE ACTION OF X-RAYS

Ya. L. Shekhtman and T. G. Ratner

1. With the object of studying the kinetics of the fading of Methylene blue in aqueous solution under the action of ionizing radiations, we investigated the relation of the fading of an aqueous solution of Methylene blue to the acidity of the solution within the concentration range of 40–1000 micromoles per liter.

2. It was shown that fading depends on the pH of the solution and has a minimum at pH 4. In weakly acid solutions (pH 5.5) in presence of oxygen, fading proceeds irreversibly in accordance with an exponential law and is dependent on the initial concentration of the solution.

Between the 37% dose, i.e. the dose necessary for the destruction of 63% of the original dye molecules, and the initial dye concentration C₀ there is a linear relationship:

$$C_0/D_0 = K$$

In accordance with these results and the analytically derived reaction equation (it may be supposed that fading products of the dye react with active radicals formed in the water, these fading products having the same "affinity" for radicals as the original dye molecules have. The yield obtained in the reaction does not depend on concentration.

3. In acid solutions (pH 1.0) there is no linear relation between C_0 and D_0 ; the ratio C_0/D_0 and the yield in the reaction increase with increase in concentration.

4. We used an aqueous solution of Methylene blue as an indicator in the investigation of the "affinity" to active radicals shown by certain organic compounds: urea, thiourea, cysteine, cystine, and glucose. The "protection" coefficients calculated from the results are in accord with Dale's results, which are obtained with carboxypeptidase as indicator. This method can be used in the food industry in radiational sterilization of food products.

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SYNTHESIS AND TRANSFORMATIONS OF LEUCO COMPOUNDS OF DYES UNDER THE ACTION OF Co^{60} γ -RADIATION

I. V. Vereshchinsky, L. T. Karpushkin, and V. N. Shcheglov

1. The decolorization of dye solutions under the action of ionizing radiations has been investigated by several authors. In the present work an investigation was made into the conditions for the formation of the colored forms of dyes from the corresponding leuco compounds under the action of Co^{60} γ -radiation.

2. Leuco compounds of various triarylmethane dyes were synthesized (Malachite green, Brilliant green, Crystal violet, Methyl violet, Basic blue K). When methanol solutions of the leuco compounds are irradiated with γ -rays, the corresponding dyes are formed. Reaction requires the presence of molecular oxygen in the system.

3. When γ -radiation acts on a mixture of ethanolic solutions of 1-naphthol and p-phenylenediamine in presence of molecular oxygen, the synthesis occurs of the dye Indophenol blue. In absence of molecular oxygen the leuco form is formed, and this is converted into the dye during subsequent contact with molecular oxygen.

4. The possible mechanism of the radiation-induced reactions occurring is discussed.

Institute of Physical Chemistry of the Academy of Sciences of the USSR

EFFECT OF IRRADIATION OF PROTEIN SOLUTIONS WITH X-RAYS IN AIR AND IN A VACUUM

T. E. Pavlovskaya and A. G. Pasynsky

In our previous investigations (Colloid J. 14, 239, 1952; 17, 305, 1955), by the methods of infrared and ultraviolet spectrophotometry (particularly ultraviolet), it was shown that the changes in absorption due to the action of the ionizing radiations, which are attributed in the literature (Barron and others) entirely to chemical changes undergone by the protein during irradiation, are in large measure due to Rayleigh scattering by aggregated protein particles; only a residual effect in the change in true absorption (after subtraction of the Rayleigh correction, which attains 20-40% of the total effect) should be attributed to chemical changes brought about by irradiation in the chromophoric groups of the protein.

In the present investigation we have developed a method of eliminating the effect of scattering in the measurement of absorption spectra by comparison with "standard" suspensions (quartz in glycerol, palmitic acid in water, etc.). A comparison is made of the changes in the true absorption of protein solutions when irradiated with X-rays in the air and in a vacuum (doses of up to 500,000 roentgens). The changes in the true absorption of protein solutions, when irradiated in a vacuum, are determined by the action of H and OH radicals and hydrogen peroxide. Introduction into these solutions of sodium octanoate or cysteine, which react with the oxidizing component of irradiated water, enables us to eliminate the effect of OH radicals and hydrogen peroxide on the chromophoric groups of the protein. When this is done, the change in the true absorption of the protein during irradiation is reduced by 55-50%. In this way we may determine approximately by difference the relative content of H radicals for irradiation in a vacuum.

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ACTION OF Co^{60} γ -RADIATION ON PROTEINS AND AMINO ACIDS

M. A. Khenokh and E. M. Lapinskaya

This paper gives results on the action of γ -radiation on proteins and amino acids. Co^{60} (about 2 curies) was used as source of radiation. The findings are as follows.

1. In 0.5% solutions of albumin, casein, and gelatin, γ -radiation (dose $7.5 \cdot 10^{19}$ ev/cc) causes an increase in ultraviolet absorption in the region 230-300 m μ . No new maxima appear.

2. Irradiation of a 5% gelatin gel (dose about $11.5 \cdot 10^{19}$ ev/cc) results in its conversion into a form that is insoluble in water at 50-60°. γ -Radiation reduces the ability of gelatin to swell and causes a gel to become capable to only limited swelling even at elevated temperature, which is probably to be explained by the formation of cross links during irradiation.

3. In amino acid solutions, oxidative processes occurring under the action of γ -radiation cause deamination with liberation of ammonia and rupture of C—C bonds in carbon chains with formation of formaldehyde (dose about $11 \cdot 10^{19}$ ev/cc).

4. It was established with the aid of paper chromatography that, when irradiated, amino acids are decomposed with formation of amino acids having a shorter chain. Analogous results were obtained by the action of Fenton's reagent on amino acids.

5. Under the action of γ -radiation at a dosage of $0.8 \cdot 10^{19} - 1.0 \cdot 10^{19}$ ev/cc, solutions of the aliphatic amino acids, glycine, alanine, leucine, and histidine show an increase in optical density. In cystine solutions irradiated at a dosage of $9.5 \cdot 10^{19} - 21.3 \cdot 10^{19}$ ev/cc, the absorption in the ultraviolet region is reduced.

6. In solutions of the aromatic amino acids phenylalanine and tyrosine, the action of γ -radiation at a dose of $1.8 \cdot 10^{19} - 4.8 \cdot 10^{19}$ ev/cc results in increased absorption in the ultraviolet region, but no new absorption maxima are formed. In tryptophan solutions irradiation results in a reduction in absorption ($2.8 \cdot 10^{19} - 8.0 \cdot 10^{19}$ ev/cc).

Oxidative reactions due to the action of γ -radiation ($1.8 \cdot 10^{19} - 5.4 \cdot 10^{19}$ ev/cc) cause hydroxylation of the six-membered ring of phenylalanine with formation of phenols.

7. Irradiation of aqueous solutions of benzene results in increase in optical density in the region 230-280 m μ . New sharp absorption bands at 260 and 276 m μ are found in the absorption spectrum of irradiated benzene solution, thus indicating the formation of phenol. It was shown also that a new absorption region (305-370 m μ with maximum at 348 m μ) makes its appearance. The action of γ -radiation on aqueous solutions of benzene results in the rupture of C-C bonds in the benzene ring with formation of formaldehyde.

8. The γ -irradiation of aqueous solutions of toluene at a dosage of $1.46 \cdot 10^{19} - 2.56 \cdot 10^{19}$ ev/cc causes the formation of a new absorption region (340-370 m μ with a maximum at 355 m μ). The absorption in the region 230-280 m μ is preserved.

The results of spectrum analysis on irradiated phenol solutions show that γ -radiation (dose $4.92 \cdot 10^{19} - 8.99 \cdot 10^{19}$ ev/cc) has no appreciable effect on the absorption spectrum of these solutions. Comparison of the effect of γ -radiation on the spectra of aqueous solutions of benzene, toluene, and phenol showed that the phenol spectrum is the most stable to the action of ionizing radiation.

9. Experiments on the effect of free radicals (Fenton's reagent) on benzene solutions showed that changes occur in the benzene spectrum (in the region 230-280 m μ) which are analogous to those produced by γ -rays.

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EFFECT OF IONIZING RADIATIONS ON ANIMAL FATS

B. N. Tarusov

1. A study was made of the kinetics of changes in physicochemical properties (viscosity, spectral characteristics, peroxide numbers, etc.) and in toxic properties of fats isolated from the livers of mammals and fish and then irradiated with x- and γ -rays.

2. In fats irradiated in presence of oxygen, active products are formed and postirradiation reactions occur which proceed by a branched-chain mechanism with formation of toxic products.

3. Sterols are natural inhibitors for this reaction. The development of the oxidative chain reaction is ensured by a parallel reaction which destroys the inhibitor and also proceeds by a chain mechanism.

4. In presence of water there is a considerable acceleration of reaction and a high yield of highly toxic unsaturated acids is obtained. The accumulation of unsaturated acids in the postirradiation reaction shows no parallelism with the formation and accumulation of peroxide compounds.

5. A study was made of the dependence of reaction rate on dose, temperature, oxygen content, and amount of water.

6. On the basis of a comparison of these results with results obtained on living organisms, it is suggested that analogous reactions, accompanied by the formation of highly toxic unsaturated fatty acids, occur in the fatty phases of organisms.

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EFFECT OF THE γ -RADIATION OF RADIOACTIVE COBALT ON THE ABSORPTION SPECTRA OF CARBOHYDRATES

M. A. Khenokh

This paper gives data on the effect of γ -radiation on carbohydrate solutions. The source of radiation was Co^{60} (about 2 curies).

The findings are as follows.

1. The ultraviolet absorption of starch solutions increases as the dosage increases from $1.7 \cdot 10^{19}$ to $8.8 \cdot 10^{19}$ ev/cc. At the same time, an absorption maximum is formed at 264.5-265 m μ and a minimum at 240 m μ .

2. In inulin solutions at dosages of $0.72 \cdot 10^{19} - 10 \cdot 10^{19}$ ev/cc, the absorption maximum lies at 271 m μ and the minimum at 240 m μ . Increase of dosage causes a displacement of λ_{max} and λ_{min} in the direction of the shorter waves and the establishment of a stable maximum at 265 m μ with a minimum at 230-232 m μ . According to data in the literature, this corresponds to the absorption spectrum of dihydroxyacetone.

3. In glucose solutions at dosages of $2.4 \cdot 10^{19} - 24 \cdot 10^{19}$ ev/cc, products are formed with an absorption maximum at 258-260 m μ and a minimum at 232 m μ . In fructose solutions at dosages of $1.7 \cdot 10^{19} - 4.8 \cdot 10^{19}$ ev/cc, the maximum and minimum are at 264-265 m μ and 232-230 m μ , respectively.

4. In solutions of carbohydrates named in paragraphs 1, 2, and 3, and also in solutions of other sugars, oxidative processes occurring under the action of γ -rays cause rupture of C-C bonds in the carbohydrate chains with formation of formaldehyde.

5. In maltose solutions at dosages of $1.8 \cdot 10^{19} - 5.4 \cdot 10^{19}$ ev/cc, λ_{max} lies at 262 m μ and λ_{min} at 252 m μ . In lactose solutions the corresponding wavelengths are 264-265 m μ and 240 m μ .

6. Irradiation of sucrose and raffinose solutions ($0.85 \cdot 10^{19} - 3.80 \cdot 10^{19}$ ev/cc) causes the appearance of a maximum at 265-264 m μ and of a minimum at 231 m μ .

7. Qualitative and quantitative chromatographic analysis on paper showed that in γ -irradiated sucrose and raffinose solutions hydrolysis occurs with rupture of the 1,2-bond in sucrose and the 1,6-bond in raffinose. In the radiolysis of sucrose solutions the fructose yield was 1.48 molecules per 100 ev, and in the radiolysis of raffinose solutions it was 0.36 molecule per 100 ev.

8. Irradiation of mannitol solutions resulted in the appearance of an absorption maximum at 265 m μ and a minimum at 230 m μ .

In the irradiated solutions fructose is formed in a yield of 0.5 molecule per 100 ev.

Under the action of γ -radiation, carbohydrates not only undergo decomposition, but also undergo simultaneous transformations in which the original number of carbon atoms in the molecule is preserved.

9. The results of this work may be of practical interest in connection with attempts to make use of ionizing radiation for the destruction of macromolecular carbohydrates and also for sterilization, for example in the food and pharmaceutical industries.

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1. The ultraviolet absorption of starch solutions increases as the dosage increases from $1.7 \cdot 10^{18}$ to $8.8 \cdot 10^{18}$ ev/cc. At the same time, an absorption maximum is formed at 264.5-265 m μ and a minimum at 240 m μ .

2. In inulin solutions at dosages of $0.72 \cdot 10^{18} - 10 \cdot 10^{18}$ ev/cc, the absorption maximum lies at 271 m μ and the minimum at 240 m μ . Increase of dosage causes a displacement of λ_{max} and λ_{min} in the direction of the shorter waves and the establishment of a stable maximum at 265 m μ with a minimum at 230-232 m μ . According to data in the literature, this corresponds to the absorption spectrum of dihydroxyacetone.

3. In glucose solutions at dosages of $2.4 \cdot 10^{18} - 24 \cdot 10^{18}$ ev/cc, products are formed with an absorption maximum at 258-260 m μ and a minimum at 232 m μ . In fructose solutions at dosages of $1.7 \cdot 10^{18} - 4.3 \cdot 10^{18}$ ev/cc, the maximum and minimum are at 264-265 m μ and 232-230 m μ , respectively.

4. In solutions of carbohydrates named in paragraphs 1, 2, and 3, and also in solutions of other sugars, oxidative processes occurring under the action of γ -rays cause rupture of C-C bonds in the carbohydrate chains with formation of formaldehyde.

5. In maltose solutions at dosages of $1.8 \cdot 10^{18} - 5.4 \cdot 10^{18}$ ev/cc, λ_{max} lies at 262 m μ and λ_{min} at 252 m μ . In lactose solutions the corresponding wavelengths are 264-265 m μ and 240 m μ .

6. Irradiation of sucrose and raffinose solutions ($0.85 \cdot 10^{18} - 3.80 \cdot 10^{18}$ ev/cc) causes the appearance of a maximum at 265-264 m μ and of a minimum at 231 m μ .

7. Qualitative and quantitative chromatographic analysis on paper showed that in γ -irradiated sucrose and raffinose solutions hydrolysis occurs with rupture of the 1,2-bond in sucrose and the 1,6-bond in raffinose. In the radiolysis of sucrose solutions the fructose yield was 1.48 molecules per 100 ev, and in the radiolysis of raffinose solutions it was 0.36 molecule per 100 ev.

8. Irradiation of mannitol solutions resulted in the appearance of an absorption maximum at 265 m μ and a minimum at 230 m μ .

In the irradiated solutions fructose is formed in a yield of 0.5 molecule per 100 ev.

Under the action of γ -radiation, carbohydrates not only undergo decomposition, but also undergo simultaneous transformations in which the original number of carbon atoms in the molecule is preserved.

9. The results of this work may be of practical interest in connection with attempts to make use of ionizing radiation for the destruction of macromolecular carbohydrates and also for sterilization, for example in the food and pharmaceutical industries.

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EFFECT OF γ -RADIATION ON THE ABSORPTION SPECTRA OF NUCLEIC ACIDS AND OF PYRIMIDINE AND PURINE BASES

T. N. Rysina

1. The problem of the action of ionizing radiation on nucleic acids and allied compounds attracts much attention from investigators in connection with the considerable sensitivity of these compounds toward radiation and their direct participation in fundamental biological processes.

2. A study was made of the ultraviolet absorption spectra of solutions (of various concentrations) of purine and pyrimidine bases of biological importance, and also of adenosinetriphosphoric, deoxyribonucleic, and ribonucleic acids, after γ -irradiation in doses of 1,000 to 20,000 roentgens.

3. The ultraviolet absorption spectra of most of the solutions investigated were altered by γ -irradiation. The optical density at the absorption maximum was reduced in proportion to the dose.

4. The results indicated that pyrimidines are more sensitive to radiation than the purines. The changes effected in the absorption spectra of nucleic acids are less than those for the pyrimidine bases, but greater than those for the purines.

Differences in the sensitivity to radiation of individual pyrimidines and purines were noted.

The paper discusses the causes of the different radiational sensitivities of the compounds investigated.

5. This work enables us to conclude that the effect of ionizing radiations on nitrogenous bases is an indirect one.

Academy of Medical Sciences of the USSR

SIGNIFICANCE OF THE IONIZATION OF IRON-CONTAINING COMPOUNDS DURING THE IRRADIATION OF AN ORGANISM WITH X-RAYS

S. E. Manolilov

The topics discussed in the paper are concerned with the possibility of the direct ionization by x-rays of metal-containing substances, particularly the iron compounds that form components of enzymes which bring about biological oxidation in living organisms. On the basis of results obtained experimentally both *in vivo* and *in vitro*, it is concluded that, during treatment with ionizing radiations, there is a specific attack on iron-containing compounds of great importance for the life processes of the organism.

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ISOMERIZATION OF XYLENES UNDER THE ACTION OF γ -RADIATION

A. I. Gelbshtein, M. I. Temkin, G. G. Sheglova, T. V. Ilyukhina,
and M. A. Proskurnin

Under the action of ionizing radiation, hydrocarbon molecules lose electrons with the creation of electronic configurations which, according to Whitmore and Dewar, make it possible for molecular arrangements to occur. In particular, loss of an electron by a xylene molecule should lead to the formation of a carbonium ion capable of undergoing isomerization.

On the basis of these considerations we carried out experiments in which pure o-, m-, and p-xylenes were subjected to the action of γ -radiation at room temperature. The irradiated samples were analyzed with the aid of ultraviolet absorption spectra.

Under the action of γ -radiation, each of the three xylenes is isomerized into the other two. The lowest yield of isomers is given by o-xylene (2 molecules per 100 ev), and the highest by p-xylene (6 molecules per 100 ev). The number of acts of reaction occurring for each act of ionization is two in the case of the isomerization of p-xylene. This can be explained by the transfer of an electron from one molecule to another or by the participation of activated molecules in the reaction. Addition of 0.2 mole % of the electron acceptor CBr_4 has no effect on the yield of products.

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TRANSFORMATIONS OF GASEOUS SATURATED HYDROCARBONS AND ETHYLENE UNDER THE ACTION OF FAST ELECTRONS

B. M. Mikhailov, M. V. Tarasova, V. G. Kiselev, and V. S. Bogdanov

I. Saturated Hydrocarbons

1. A study was made of the effect of 90-kev electrons on gaseous aliphatic hydrocarbons (methane, ethane, propane, and butane). The effects of the pressure of the irradiated gas and the duration of irradiation on the radiolysis of the hydrocarbons were determined.

2. The main reaction in the radiation-induced transformations of these hydrocarbons is dehydrocondensation. Methane undergoes 50% conversion into liquid saturated hydrocarbons, and ethane, propane, and butane are similarly transformed to the extent of 70-90%. A characteristic of the radiolysis of these hydrocarbons is the insignificant extent to which the lower gaseous unsaturated hydrocarbons are formed.

3. The stabilities of methane and propane toward radiolysis are approximately the same; as we pass to propane and butane the stability increases.

4. The amount of hydrocarbon transformed increases with increase in dosage intensity, pressure of irradiated gas, and duration of irradiation.

II. Ethylene

1. An investigation was made into the transformations of ethylene under the action of a beam of fast electrons.

The effects on the course of reaction of duration of irradiation, pressure, and dilution of the original ethylene with nitrogen were determined.

2. It was found that the radiolysis of ethylene gives mainly butane, acetylene, and liquid products.
3. Apart from butane and acetylene, the gaseous reaction products contain very small amounts of hydrogen, methane, ethane, and butenes, and also traces of propane and propene.
4. The liquid products boiling below 130° consist of hexanes, hexenes, octanes, and octenes. The higher fractions contain appreciable amounts of aromatic and unsaturated hydrocarbons.
5. The reaction has a G-value of 16 molecules per 100 ev.
6. It was found that, under the same irradiation conditions, rarefaction of the ethylene, while not appreciably affecting the composition of the product, somewhat increases the extent to which the ethylene is decomposed.
7. Dilution with nitrogen considerably increases the extent to which the ethylene is decomposed, and it simultaneously lowers the G-value.
8. A reaction mechanism, which explains the formation of molecules having even numbers of carbon atoms, is proposed.

Institute of Organic Chemistry of the Academy of Sciences of the USSR

SOME PROBLEMS IN THE RADIATION CHEMISTRY OF MIXTURES OF ORGANIC SUBSTANCES

Kh. S. Bagdasaryan, T. S. Nikitina, and V. A. Krongauz

1. In the radiolysis of mixtures of organic substances the yield of radicals often differs from the value corresponding to the "rule of mixtures." In other words, in the general case the formation of radicals from each component of the mixture cannot be regarded as independent processes.
2. Departures from the rule of mixtures for the yield of radicals were detected with the aid of diphenylpicrylhydrazyl (DPPH) in the radiolysis of mixtures of benzene and vinyl acetate.
3. In the radiation-induced polymerization of methyl methacrylate in ethyl acetate solution, the rate of initiation is constant and is independent of the concentration of methyl methacrylate in the mixture. These results can be explained by the formation of primary radicals during radiolysis from both components of the mixture in accordance with the rule of mixtures.
4. In the radiation-induced polymerization of methyl methacrylate or styrene in mixtures with carbon tetrachloride, the rate of polymerization passes through a maximum at low contents of carbon tetrachloride, which indicates a positive departure of the yield from the rule of mixtures.
5. The rate of the chain reaction proceeding under the action of γ -rays or light and leading to the formation of the addition product of carbon tetrachloride and butyl vinyl ether passes through a maximum when the carbon tetrachloride content of the mixture is 65%.
6. The G-value for the decomposition of benzoyl peroxide in benzene solution is very great. In 0.01 M solution $G = 1760$ (calculated on the energy absorbed by the benzoyl peroxide). This result is in accord with data obtained with the aid of DPPH on the yield of radicals in this system. When additions of phenanthrene, anthracene, and benzoic anhydride are made, the rate of decomposition of the peroxide diminishes. The

results indicate transfer of energy from activated benzene molecules to benzoyl peroxide molecules with the result that the latter decompose.

7. Taken together, the results obtained by the radiolysis of solutions of benzoyl peroxide in ethyl acetate and cyclohexane indicate the absence of an effect of energy transfer from solvent molecules to benzoyl peroxide molecules. The high yield found for the decomposition of the peroxide in these solvents is due to a chain reaction.
8. The G-value for the decomposition of a 0.1 M solution of tert-butyl peroxide in benzene is 17 (calculated on the energy absorbed by the peroxide). It was concluded that there is no energy-transfer effect in this system.
9. At 30° the rate of the radiation-induced polymerization of styrene is increased three-fold in presence of 0.01 mole per liter of benzoyl peroxide. Addition of 2,2'-azobis[2-methylpropionitrile] to the styrene has no effect on the rate of polymerization.
10. The results enable us to make the general conclusion that the efficiency of the transfer of activation energy in mixtures is great only when both components are aromatic compounds.

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ACTION OF γ -RADIATION ON MIXTURES OF BENZENE AND CARBON TETRACHLORIDE WITH FLUORINE-CONTAINING SUBSTANCES

A. V. Zimin, S. V. Churmanteev, and A. D. Verina

1. There are no data in the literature on the action of γ -radiation on mixtures of benzene and CCl_4 with fluorine-containing substances. There are papers by A. V. Zimin, S. V. Churmanteev, and A. D. Verina (Collection of Papers on Radiation Chemistry, Acad. Sci. USSR Press, 1955, p. 249) and by A. V. Zimin and A. D. Verina (Collection of Papers on Radiation Chemistry, 1957) in which the effect of γ -radiation on a mixture of benzene and CCl_4 is studied.
2. In these investigations it was established that treatment of a mixture of benzene and CCl_4 with γ -radiation leads to the formation of HCl , products of the chlorination of benzene (of the benzotrifluoride type) and other nonvolatile products. The yield of volatile chlorination products of benzene did not exceed about 1 molecule per 100 ev.
3. In the present investigation we studied the effect of γ -radiation on mixtures of CCl_4 with KF , ZnF_2 , and SbF_3 and on mixtures of benzene with $\text{C}_2\text{F}_2\text{Cl}_2$ and C_2F_4 .
4. In the irradiation of mixtures of CCl_4 with KF , ZnF_2 , and SbF_3 we observed a loss of fluorine from these fluorides.
5. The least loss of fluorine was observed in KF (about 3%) and the most in SbF_3 (about 60%). For ZnF_2 the loss was about 35%.
6. After irradiation of a heterogeneous mixture of CCl_4 with ZnF_2 or SbF_3 , the latter were found to contain chloride ions, the yield of which was about 3.5 Cl^- ions per 100 ev; correspondingly, in doubly recondensed CCl_4 we detected bound chlorine in a yield of about 3 atoms per 100 ev.
7. In the mass-spectrometric analysis of doubly recondensed CCl_4 we detected an appreciable amount of mass 102, which corresponds to the CFCl_2^+ ion, which was probably formed by the electron bombardment of a CFCl_3 molecule. According to the results of N. N. Tuntitsky, S. E. Kupriyanov, and M. V. Tikhomirov

(Collection of Papers on Radiation Chemistry, Acad. Sci. USSR Press, 1955, p.223), the occurrence of such ionization accompanied by the dissociation of CFCl_3 molecules is possible.

8. After treatment of mixtures of benzene with $\text{C}_2\text{F}_5\text{Cl}$, and with C_2F_6 with γ -radiation, nonvolatile residues were found.

9. In the case of the irradiation of a mixture of benzene and $\text{C}_2\text{F}_5\text{Cl}$, the chlorine and fluorine contents of the nonvolatile residue were not equivalent. From the total halogen content of the nonvolatile residue it may be inferred that, in reacting with a $\text{C}_2\text{F}_5\text{Cl}$ molecule, the benzene molecule gives a halogenated product of benzene of the type $\text{C}_6\text{H}_5\text{C}_2\text{F}_5\text{Cl}$.

10. In the case of the irradiation of a mixture of benzene and C_2F_6 at a molar ratio of 1 : 1, the main radiolysis products are biphenyl and hydrogenated products from C_2F_6 , whereas at a molar ratio of 1 : 100 there is no appreciable amount of biphenyl and there is a nonvolatile viscous residue of fluorine content about 34.6% which corresponds closely to molecules of the type $(\text{C}_6\text{H}_5)_2\text{C}_2\text{F}_6$.

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PROSPECT OF PREPARING HEXACHLORAN BY THE ACTION OF RADIATION

P. V. Zimakov, E. V. Volkova, and L. A. Krasnushov

1. Hexachloran is a very important toxic preparation. The industrial method of preparing this compound (photochemical chlorination of benzene) gives a product having a low content (8-12%) of the main toxic constituent, the γ -isomer. The process is associated with fire and explosion hazards.

2. The data in the literature on the chlorination of aromatic hydrocarbons under the action of ionizing radiations indicates the powerful initiating action of Co^{60} γ -radiation in this reaction, the yield of chlorination products being greatly increased (up to 85,000 molecules per 100 eV of absorbed energy, as compared with 1000 for ultraviolet radiation). There are references also to the increase of the content of the γ -isomer of 1,2,3,4,5,6-hexachlorocyclohexane (HCCH) to 32% in the chlorination of benzene under pressure in presence of γ -radiation.

3. The object of our investigation was the development of a method for the preparation of HCCH by the action of radiation. It was found that in the chlorination of benzene under the action of Co^{60} radiation at low temperature (from -80 to -40°), hexachloran having an increased content of γ -isomer was formed (15-17%, instead of 10-12% in photochemical chlorination). The amount of HCCH formed is proportional to the energy absorbed. With rise in temperature to -34° a sharp increase in reaction rate was observed. In the chlorination of benzene under the action of β - and γ -radiations from a fragment source, analogous results were obtained.

4. Results are given for the chlorination of benzene with gaseous chlorine in the temperature range +20 to +60° and for the relation of reaction rate and content of various isomers to the dose of absorbed energy, the temperature, and the concentration of chlorine in benzene.

5. The prospects of manufacturing hexachloran by the radiation method are discussed.

Research Institute of the Ministry of Chemical
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DETERMINATION OF THE INDIVIDUAL PRODUCTS OF THE RADIATIONAL OXIDATION OF HEPTANE AND 2,2,4-TRIMETHYLPENTANE

V. V. Saraeva, N. A. Bakh, L. V. Rybin, and V. A. Larin

In previously published papers it was shown that, in the oxidation of hydrocarbons with molecular oxygen under the action of radiation at comparatively low temperatures, peroxide compounds, carbonyl compounds, and acids are formed. In the present paper we present results on the formation of alcohols and on the identification of individual carbonyl compounds and acids formed in heptane and 2,2,4-trimethylpentane in the region of direct proportionality between their concentrations and absorbed energy. Identification was effected by partition chromatography. The G-value of the reaction for each compound identified was determined.

2. It was shown that in heptane both aldehydes and ketones were formed and that 70% of the total amount of carbonyl compounds was 2-hexanone. Only ketones were detected in 2,2,4-trimethylpentane, and 70% of the total amount consisted of 2-methyl-3-hexanone. The bulk of the acids formed in heptane and 2,2,4-trimethylpentane contained 3-7 carbon atoms. Acetic and formic acids were formed in small amounts.

3. Comparison of the results with the mass spectra of heptane and 2,2,4-trimethylpentane indicates that, in the processes of radiational formation of carbonyl compounds in the liquid phase, no appreciable role is played by radicals, the formation of which is associated with the ionizational decomposition of molecules during electronic bombardment in discharged vapors.

The results are interpreted with the aid of concepts concerning the occurrence of nonchain radiational reactions.

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OXIDATION OF METHANE WITH OXYGEN UNDER THE ACTION OF FAST ELECTRONS

B. M. Mikhailov, M. E. Kulmova, and V. S. Bogdanov

1. The oxidation of methane with oxygen under the action of 120-keV electrons was investigated. A study was made of the effects of the composition of the original methane-oxygen mixture, the pressure, the temperature, and the duration of irradiation. The relative amounts of methane and oxygen in the mixtures were: 1 : 1, 4 : 1, and 9 : 1, the pressure were varied from 760 to 190 mm, and the duration of irradiation from 15 to 60 minutes.

2. Of the methane that reacted, 50% was converted into liquids and 50% was converted into gases. The reaction products consisted of H_2O , HCOOH , H_2 , CO , CO_2 , alcohol, peroxides, and traces of CH_2O . The main carbon-containing product of the oxidation of methane was formic acid.

3. Increase in pressure and increase in the methane content of the original mixture (from 50 to 80%) result in increase in the rate of the oxidation reaction.

4. With increase in the duration of irradiation of a methane-oxygen mixture, the relative amounts of the reaction products change only slightly and their composition remains constant.

5. The yield of the oxidation reaction was determined; it is 6 methane molecules and 7 oxygen molecules per 100 ev.

Institute of Organic Chemistry of the Academy of Sciences of the USSR

OXIDATION OF HEXADECANE UNDER THE ACTION OF γ -RADIATION

Yu. L. Khmel'nitsky, M. A. Proskurnin, E. V. Bareiko, I. I. Melekhnova,
and A. T. Slepneva

1. The initiation of oxidative chain reactions is one of the methods of utilizing ionizing radiations in chemistry and chemical technology. A process of this sort that is of great interest and practical importance is the oxidation of paraffins.

2. An investigation was made into the oxidation of paraffins of high molecular weight initiated with Co^{60} γ -radiation at various dosage intensities, the case of hexadecane being taken for study.

3. Experiments were carried out on the stability of hexadecane under Co^{60} γ -radiation in a vacuum.

4. A study of the temperature-dependence of the radiation-induced oxidation reaction based on the formation of nonvolatile carboxylic acids showed that, with rise in temperature above 120°, the reaction rate increases appreciably.

When irradiation is prolonged beyond a certain limit that is specific for each given temperature, it no longer has an appreciable effect on reaction rate.

This result is in accord with the results of N. M. Emanuel's experiments (J. Phys. Chem. 30, 4, 847, 1956, and other papers) on the effect of initiating additions on the rate of oxidation of paraffins in its initial stage.

5. On the basis of the regularities observed, a series of experiments was carried out on the conditions for the oxidation of technical paraffin.

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EFFECT OF IONIZATION DENSITY ON THE RADIOLYSIS OF HYDROCARBONS

I. V. Verishchinsky and N. A. Bakh

1. In order to make a comparison with previous results on the radiation-induced oxidation of hydrocarbons under the action of X-rays and fast electrons, in the present investigation we have studied the effect of the radiation of a deuterium nuclear reactor on liquid benzene and cyclohexane in presence and absence of molecular oxygen.

2. In the liquid phase, among the products of the radiational oxidation of benzene, phenol, aldehydes, and small amounts of peroxides were detected. Among the oxidation products of cyclohexane, hydroperoxides, disubstituted peroxides, cyclohexanone, and acids were found.

3. In the gaseous products of the radiolysis of benzene under low pressure, hydrogen and acetylene were found. The G-value of the reaction with respect to the polymerization product formed was about ten times as high as the yield of gaseous products. In the radiolysis of cyclohexane under low pressure, hydrogen and a polymerization product were again formed. The number of hydrogen molecules liberated was equal to the number of cyclohexane molecules converted into polymer.

4. The yield of molecular hydrogen liberated in the radiolysis of benzene rose substantially in presence of molecular oxygen. In the case of cyclohexane, the presence of oxygen had no effect on the yield of hydrogen.

5. Comparison of the G-values of the reaction for products obtained with radiation at different ionization densities enables us to make a demarcation in the mechanism by which the products are formed, distinguishing reaction between radicals from reaction between radicals and molecules.

Institute of Physical Chemistry of the Academy of Sciences of the USSR

FORMATION OF CROSS LINKS IN THE IRRADIATION OF POLYETHYLENE WITH IONIZING RADIATIONS

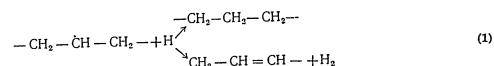
A. N. Pravednikov and S. S. Medvedev

1. The number of cross links formed in the irradiation of polyethylene with ionizing radiations is proportional to the dose and is independent of the radiation intensity. When we take into account that a stationary concentration of free radicals and double bonds is generally not attained during irradiation because of the high viscosity of the medium, this relationship indicates that each cross link is formed as the result of the absorption of one quantum of energy, which activates two neighboring polymer molecules.

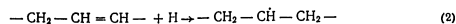
Cross linking due to the recombination of two polymeric radicals formed by the rupture of two C—H bonds under the action of radiation is not very probable owing to the comparatively great distances between these radicals and the low mobility of the chains.

2. The activation energy for cross-linking processes at above 200°K is 0.5–1 kcal/mole; at lower temperatures the activation energy is zero. In other words, below 200°K cross linking proceeds as a result of processes, the rates of which are independent of the temperature of the sample; at higher temperatures further processes are superimposed on these processes, and these also result in the cross linking of polymeric molecules; these further processes increase somewhat in rate as the temperature rises.

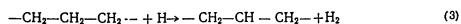
3. For an understanding of the mechanism of the processes leading to the formation of cross links, it is necessary to examine the reactions proceeding with the participation of atomic hydrogen in the polyethylene during irradiation. Clearly, in the system under consideration, atomic hydrogen may react either with the free radicals formed during irradiation:



or with double bonds:



or, finally, it may tear an H atom from a polyethylene molecule:



It may be shown that the rate of the last reaction is considerably greater than those of the first two reactions.

All these reactions (particularly Reaction 3), owing to the comparatively low rates of diffusion of gases in polyethylene, proceed mainly in the immediate vicinity of the place where the atomic hydrogen is formed (and therefore of the position of the primary radical), which will be encouraged also by the enhanced energy of H atoms formed by rupture of C—H bonds under the action of radiation. Recombination of the primary radical and the nearby radical formed by Reaction 2 (or 3) leads to the formation of cross links.

The scheme that we have examined leads to the experimentally observed kinetic laws and, in particular, to the observed relation between activation energy and temperature of the sample (the increase in the rate of cross linking probably occurs at temperatures close to the vitrification temperature of the polymer).

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PHASE TRANSFORMATIONS IN POLYMERS DUE TO THE ACTION OF NUCLEAR RADIATIONS

B. I. Zverev, V. L. Karpov, and S. S. Leshchenko

1. Irreversible change to a state of disorder in crystalline polymers as a result of the action of nuclear radiations is associated with change in molecular structure.

2. Crystalline polymers differing in chemical nature require differing amounts of absorbed energy to effect the order-disorder transition. These differences can be utilized for the comparative characterization of the lattices of polymeric crystals.

3. The method of radial-distribution curves prepared from the electron-diffraction diagrams of polymers rendered amorphous by irradiation enables us to determine some of the peculiarities of the structure of the systems formed.

4. The changes due to irradiation in the phase state of crystalline polymers are connected with changes in a whole complex of the properties of the polymers.

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LAWS OF THE RADIATIONAL DESTRUCTION OF VITREOUS POLYMERS

B. L. Tsetlin, N. G. Zaitseva, V. M. Korbut, and V. A. Kargin

The process of radiational destruction of vitreous polymers is determined both by structural changes that are general for polymers subjected to the action of radiation and also by some peculiar phenomena associated with gas formation in the mass of a vitreous material.

The over-all direction of the change in the molecular structure of a polymer is determined by the relative rates of the simultaneous processes of cross-linking and destruction. Investigation of the effect of irradiation on the thermodynamic characteristics of various polymeric materials, mainly polymers of methacrylic esters, shows that destructive processes are greatly accelerated by the presence of a quaternary carbon atom in the polymer chain; destruction is accelerated also by the introduction of substances of low molecular weight (plasticizers). Radiational-vulcanization processes are intensified by increase in the size of side chains. The presence of aromatic groups in the polymer stabilizes it with respect to the action of radiation.

Gas formation plays an important part in the radiational destruction of vitreous polymers. It brings about a complex strained condition, which is associated with shrinkage phenomena and also with the formation of supersaturated solutions. As a result of contractive internal strains, samples may form cracks, which often appear a long time after irradiation. The formation of supersaturated solutions is manifested by the appearance of gas bubbles and swellings in the samples.

An examination of the relative rates at which the mechanical-strength properties of various polymeric glasses fall during irradiation shows that both the over-all rate of the radiation-induced changes and also the relaxation properties of the material play important parts in this phenomenon.

In the irradiation of polymeric glasses with fast electrons, in several cases a peculiar phenomenon is observed: the formation of a tree-like system of internal cracks. From our investigation of this phenomenon, we concluded that it is associated with the general processes occurring in the radiation-induced decomposition of polymers; the mechanism of this kind of crack formation appears to consist in the absorption of similarly charged decomposition products of low molecular weight on micro defects, resulting in the further development of these micro defects owing to the electrostatic interaction between these products.

Our investigation of the effect of temperature on the radiation-induced destruction of polymethyl methacrylate shows that this process is irreversible. This is confirmed also by the lack of dependence of the rate of destruction of polymethyl methacrylate on the ratio between dosage intensity and duration of irradiation.

In the paper, use is made of experimental data reported in the article by B. L. Tsetlin, N. G. Zaitseva, V. M. Korbut, and V. A. Kargin entitled "Effect of High Energy Radiation on Polymeric Glasses" which has been submitted for publication in the Collection of Papers on Radiation Chemistry (1967), and also in the report by B. L. Tsetlin, N. G. Zaitseva, and V. A. Kargin, which has been submitted for publication in the Proceedings of the Academy of Sciences of the USSR.

Institute of Physical Chemistry of the Academy of
Sciences of the USSR

PROCESSES OF GAS LIBERATION IN POLYMERS UNDER THE ACTION OF NUCLEAR RADIATIONS

I. Ya. Petrov and V. L. Karpov

1. Investigation of processes of gas liberation (the yield and composition of the gaseous products) during the irradiation of polymers aids in the characterization of the chemical reactions that are occurring in the polymer molecules.
2. The yields and compositions of the gaseous fractions formed during irradiation are primarily determined by the molecular structure of the polymer and the conditions of irradiation (intensity, dose, temperature, etc.).
3. Processes of gas liberation are related to the relative stability of the polymer to the action of radiation. Results of the investigation of gas liberation may be used for characterizing stability to radiation.
4. The possibility of controlling gas-liberation processes and stability to radiation of polymers by modification of molecular structure, is discussed.

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ROLE OF GAS FORMATION IN THE DESTRUCTION OF POLYMERS UNDER THE ACTION OF RADIATION

A. B. Taubman and L. P. Yanova

1. Investigation of the effect of accelerated electrons on gas formation in polymers, and also on their diffusional permeabilities and mechanical properties, shows that the character of their destruction depends on the correspondence between two concurrent processes with respect to their intensities. These processes are 1) destruction of macromolecules or the tearing-off of side groups, which is accompanied by the formation of gaseous decomposition products of low molecular weight, and 2) cross-linking between individual units of the polymer chains with formation of a three-dimensional network.
2. In polymers in which irradiation causes rapid destruction (polytetrafluoroethylene, polymethyl methacrylate), the destruction process is determined not only by the depolymerization of chains, but also by gas formation, which results in the formation of additional internal stresses and so causes increased brittleness.
3. When polytetrafluoroethylene, polymethyl methacrylate, and polyethylene are subjected simultaneously to irradiation and elevated temperature, gas formation is only slightly intensified; but when the polymer passes into a molten condition, the intensity of gas formation rises suddenly over a short temperature range. It follows from this that the processes of destruction and removal of side groups of macromolecules are reversible and that, in the fusion of polymers, equilibrium in the process destruction $\rightleftharpoons$ recombination of free radicals is displaced to the left as a result of increase in the rate of diffusion of gas molecules in the mass of the polymer and the consequent facilitation of the formation of a new gas phase in the form of bubbles.
4. The gas-permeability of polymers and the way in which it changes under the action of radiation affect the destruction processes. High original gas-permeability which is increased during irradiation is favorable to the preservation of the original mechanical properties of the polymer, and vice versa. Hence, the sensitivity to radiation of polymers that have received a powerful destructive treatment is increased if they have low gas-permeability, which limits the possibility of the removal of the gases formed from the mass of the sample. The important factor in these considerations is not the absolute amount of gas formed, but the ratio of the rates of its formation and separation.

When it is difficult for the gas to get away, even for feeble gas formation, the polymer may change greatly in mechanical properties and be degraded even with relatively low doses of radiation (e.g. polytetrafluoroethylene). On the other hand, under conditions under which gas can readily escape, the polymer may preserve its original properties to a considerable extent even when the amount of gas formed is large and much higher doses of energy are given (e.g. polyethylene, polyvinyl chloride).

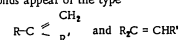
Institute of Physical Chemistry of the Academy of
Sciences of the USSR

CHEMICAL CHANGES IN SOME VINYL POLYMERS UNDER THE ACTION OF IONIZING RADIATIONS

N. A. Slovokhotova

1. In vinyl polymers subjected to the action of ionizing radiations, degradation and cross-linking processes occur, the predominance of one or other process being dependent on the structure of the polymer. In polymers containing quaternary carbon atoms in the main chain (polyisobutene, polymethyl methacrylate), degradation processes predominate, and in other polymers (polyethylene, polymethyl acrylate) cross-linking processes predominate.

On the basis of an investigation of the infrared spectra of polymers it was shown that, in the irradiation of polyisobutene and polymethyl methacrylate with ionizing radiations, side groups are torn from the main chain; in polyisobutene double bonds appear of the type



whereas in polyethylene conjugated double bonds of the type $\text{RHC}=\text{CHR}'$ (trans) appear.

3. The predominance of processes of degradation or of cross linking during irradiation may be explained by the varying stabilities of the free radicals formed in these polymers and by the dependence of the possibility of energy migration along the polymer chain on the structure of the polymer.

4. In the irradiation of polyisobutene and polyethylene in a carbon dioxide atmosphere, carbonyl groups make their appearance, this being established by the presence of the corresponding absorption bands in the infrared spectra of the polymers.

It was shown by the method of labeled atoms that direct carboxylation of the polymer molecules occurs.

L. Ya. Karpov Physicochemical Institute of the
Ministry of Chemical Industry of the USSR

RADIATIONAL VULCANIZATION OF RUBBERS

T. S. Nikitina, A. S. Kuzminsky, L. A. Oksentevich, and V. L. Karpov

1. An investigation was made into the radiational vulcanization of the following rubbers: natural (NK), butadiene-styrene (SKS-30), butadiene (SKB-40), nitrile (SKN-26), silicone (dimethylsiloxane).

The radiation used consisted of X-rays having the parameters 80 kv and 200 ma.

It was shown that there is a relationship between the dose of radiation and the density of the three-dimensional network formed during radiation on the one hand, and the strength properties on the other.

The rubbers investigated can be arranged in the following order with respect to diminution in the rate of a three-dimensional network under identical conditions: silicone, SKN-26, SKB-40, SKS-30, and NK.

NK was found to have a low tensile strength, as compared with samples prepared with standard straight sulfur vulcanizers. It is suggested that the low strength of NK radiational vulcanizates is due to loss of the ability to crystallize when stretched, this being caused by radiation-induced changes in the rubber.

Data are given which characterize the radiation-induced processes occurring in rubbers during irradiation.

2. An examination was made of the effects of some of the main ingredients of rubber mixes on the radiational-vulcanization process and of the peculiar behavior of these mixes in this process. It was shown that sulfur and tetramethylthiuram disulfide reduce the rate of the process, some compounds (diphenylguanidine, mercaptobenzothiazole) have almost no effect, and compounds containing heavy atoms (ZnO, chalk, kaolin) somewhat increase the rate of the process.

A hypothesis was advanced concerning the inhibiting effect of sulfur-containing compounds and the acceleration of the cross-linking process owing to the increased absorption of X-rays by compounds containing heavy atoms (the accelerating effect of the latter is not found when Co^{60} radiation is used in the process).

3. Data were obtained concerning the part played by carbon black in the radiational-vulcanization process. It was shown that both gas carbon and lamp black are sufficiently "active", chemical bonds between the rubber and the carbon black being formed.

Some information was obtained concerning the significance of the degree of oxidation of the carbon black in this process.

Research Institute of the Rubber Industry and L. Ya. Karpov Physicochemical Institute of the Ministry of Chemical Industry of the USSR

EFFECT OF IRRADIATION ON THE PROPERTIES OF SILICONE RUBBERS

Yu. S. Lazurkin and G. P. Ushakov

Experiments were carried out on the γ -irradiation of silicone rubbers, including polydimethylsiloxane, with the object of investigating their stability to radiation and the possibility of preventing their crystallization at low temperatures. During irradiation, silicone rubbers undergo various changes.

1. Owing to cross-linking, the elasticity modulus rises linearly with dosage for doses ranging to 500-600 $\times 10^6$ roentgens. At 400×10^6 roentgens, it is increased by a factor of 14-18.

2. Up to 400×10^6 roentgens, the vitrification temperature remains almost unchanged (-120 to -125°), but it then begins to rise somewhat, attaining -110 to -115° at 1100×10^6 roentgens.

3. As cross-linking proceeds, the rate and extent of crystallization falls and there is a lowering of melting point that is approximately proportional to the dose (from -35° for the original substance to -55° for material that has received 170×10^6 roentgens).

4. Samples that have received more than 400×10^6 roentgens almost cease to crystallize. Although there may be signs of crystallization after a long time, the melting point appears to lie below -80°.

5. At a dose of $400-500 \times 10^6$ roentgens, hard rubbers having a modulus of 200-250 kg/sq cm and high stability to frost ($T_g = -115$ to -120°) are obtained. Although their strengths at room temperature are in the range 30-40 kg/sq cm, i.e. do not differ from that of the original rubber (when calculated for the initial cross section), the extension at break is very low (15-20%).

6. Cross linking is not the only process proceeding during irradiation. In the present investigation other processes (formation of an unsaturated structure, degradation) were not studied.

Our estimation of the closeness of structure of the three-dimensional network formed in a silicone rubber by radiational cross-linking (estimated from the specific swelling and the elasticity modulus) shows that crystallization is almost entirely suppressed when there is one cross link per 10-15 monomer units.

Laboratory of Measuring Apparatus of the Academy of Sciences of the USSR

STRUCTURE AND PROPERTIES OF VULCANIZATES OBTAINED BY THE ACTION OF NUCLEAR RADIATIONS

Z. N. Tarasova, M. Ya. Kaplunov, V. N. Kuleznev, and B. A. Dogadkin

1. An investigation was made into the structure and properties of the radiational vulcanizates of SKB, NK, SKS-30A, SKS-30AM, and SKI and their carbon mixes obtained by irradiation in an atomic reactor at a dose of $1-5 \times 10^7$ roentgens.

It was shown that, with respect to the extent of cross linking, the rubbers fall into the series: SKB > NK > SKS-30A > SKI.

2. Natural rubber vulcanized by irradiation has a thermomechanical stability that is superior to that of vulcanizates obtained with thiuram without sulfur, and it shows the least change in properties in the process of "chemical relaxation of stress", which indicates the formation of bridge linkages of the C-C type.

3. With the aid of infrared spectra it was established that carboxyl, hydroxyl, and ester groups are present in the vulcanizates of NK, SKS-30A, and SKB obtained by irradiation in air.

It was shown that there is a reduction in the degree of crystallization occurring in the stretching of natural rubber vulcanized by irradiation (as compared with sulfur-vulcanized rubber).

4. The physicochemical and hysteresis properties, and also the durability to repeated deformation, were determined for rubber-carbon mixtures subjected to radiational vulcanization. As compared to sulfur vulcanizates, these products have somewhat low strength characteristics, low residual deformations, low hysteresis, and high durability to repeated deformation.

5. In contrast to the case of sulfur vulcanizates, the thermomechanical stability of rubber-carbon mixtures subjected to radiational vulcanization is substantially higher than that for unfilled rubber, the difference being greatest for active carbons.

6. It was shown that natural rubber can be crosslinked with butadiene-styrene rubber by the irradiation of a mixture of these rubbers.

Research Institute of the Tire Industry

CHANGE IN THE CAPACITY OF SOVIET ION-EXCHANGE RESINS UNDER THE ACTION OF IONIZING RADIATIONS

A. P. Smirnov-Averin, Yu. G. Sevastyanov, and G. A. Popov

1. A study was made of the stability to radiation of Soviet ionites of the types KU-2, SBS, EDE-YuP, and MMG 1, for which no data are given in the literature.

2. Results were obtained concerning the change in the exchange capacity of these ionites produced by γ -radiation.

3. The dosage intensity was measured with a ferrous sulfate dosimeter. The dose was 10^{22} to $5 \cdot 10^{22}$ ev of absorbed energy per gram of resin.

The effect was investigated of α and β -activities introduced into cationites by irradiation with neutrons from absorbed beryllium and silver.

Physical Institute of the Principal Directorate on the Utilization of Atomic Energy

PRINCIPLES UNDERLYING THE RATIONAL SELECTION AND COMPOUNDING OF PLASTICS COMPOSITIONS INTENDED FOR THE CONSTRUCTION OF MEANS OF INDIVIDUAL PROTECTION IN WORK WITH RADIOACTIVE MATERIALS

S. I. Gorodinsky, V. L. Karpov, L. M. Nosova, and M. N. Shteding

1. High-polymer materials used for the preparation of means of individual protection must conform to several special requirements, particularly ready cleansability from radioactive contamination so that it is possible to use the material repeatedly.

Among other equally important requirements are good mechanical properties, high elasticity, fairly high resistance to wear, and very low water-absorption. These requirements should be satisfied by any sort of polymeric material intended for the preparation of means of individual protection.

2. Components usually present in polymeric materials, e. g. plasticizers, stabilizers, fillers, dyes, etc., have substantial effects on the sorption-desorption properties of the material.

3. In order to select the best polymeric materials from the point of view of the special requirements, methods for the assessment of sorption-desorption properties were developed. Use of these methods has enabled us to characterize a wide range of polymeric materials and compositions.

4. Detailed investigations were made of compositions based on polyvinyl chloride, polyethylene, and other polymers. The effects of factors in the technological treatment and of individual components of the compositions on the special properties of the polymeric materials were studied.

5. On the basis of our investigations we have enunciated the principles underlying the rational selection and compounding of compositions of high-polymer materials that satisfy both the special requirements and also the technological requirements. Various materials are suggested for possible use in the preparation of means of individual protection.

L. Ya. Karpov Physicochemical Institute of the Ministry of Chemical Industry of the USSR

SOURCES OF IONIZING RADIATIONS FOR INVESTIGATIONS IN RADIATION CHEMISTRY (developed in the Institute of Physical Chemistry of the Academy of Sciences of the USSR)

V. I. Zatulovsky

In connection with investigations in radiation chemistry it was necessary to develop and prepare sources of ionizing radiations. Two types of source were developed: specialized x-ray apparatus and apparatus working with radioactive cobalt preparations.

1. X-Ray Apparatus

1. In investigations in radiation chemistry, objects of considerable area are irradiated. The necessity of having the maximum possible doses of radiation makes it essential to use x-ray tubes having large exit windows and working at very high power for long periods. In many problems the tension across the tube must be of the order of 70-100 kv maximum.

2. For these investigations we constructed specialized dismountable x-ray tubes and developed generators for feeding them. Evacuating apparatus was designed, and it was constructed entirely of metal; it enabled us to attain a vacuum of $\sim 8 \cdot 10^{-6}$ mm in the tubes.

3. The paper gives a short description of the powerful dismountable tubes: a) with a cylindrical tungsten anode (Model TRTs-3a) and b) with a half-cylindrical tungsten anode (Model TRP 1). The tubes work at a p.d. of up to 90 kv maximum with an anode current of up to 200 ma. Data are given on the intensity of radiation of the tubes and their use characteristics. For comparison, the same information is given for the sealed tube, Model BFV-70, manufactured by the MRTF works for x-ray spectrum analysis and used by the Institute of Physical Chemistry in radiation chemistry.

4. The paper gives a short description of the generating apparatus (Type ARKh-90-200) for feeding the tubes referred to in Paragraph 3. The nominal rating of the apparatus is 90 kv maximum, anode current 200 ma. The apparatus has a 4-kenotron rectifier in which V 1-0.3/70 kenotrons are used, a smooth continuous voltage regulator, and stabilization of the potential difference for the filaments of the tube and the kenotrons. Data acquired in the course of the use of several sets of ARKh-90-200 apparatus are given.

5. Together with these tubes and the ARKh-90-200 apparatus, a small-scale x-ray apparatus (Type ARKh-100-20) was developed with a short-focus dismountable tube, Model TRB-3. The nominal rating of the apparatus is 90 kv maximum, anode current 20 ma. Data are given on the intensity of the radiation of the tube and the use characteristics of the apparatus.

II. Co⁶⁰ Apparatus

6. The paper states the basic principles upon which the design of the apparatus was based, and it describes the apparatus which has now been working for two years with a Co⁶⁰ preparation equivalent in activity to 400 g-equiv of radium. Matters concerning the protection of personnel from radiation and the dosimetry of useful radiation are examined.

7. The design and use characteristics of x-ray and cobalt apparatus are compared.

Institute of Physical Chemistry of the Academy of Sciences of the USSR

MINIATURE-SCALE PREPARATORY WORK ON POSSIBLE INDUSTRIAL APPARATUS FOR CARRYING OUT RADIATION-INDUCED REACTIONS WITH THE AID OF ISOTOPIC SOURCES OF RADIATION

A. Kh. Breger and Yu. S. Ryabukhin

1. Possible industrial apparatus for radiation-induced reactions and conditions necessary for miniature-scale preparatory work on this apparatus. Character of the radiation, types of sources, intensity of the dose and its distribution in the working spaces of the apparatus, sizes of the objects to be irradiated, remote control and inspection of the physicochemical conditions of the experiments and processes occurring in the objects of investigation during the irradiation.

2. Isotopic apparatus for investigations in radiation chemistry at the L. Ya. Karpov Physicochemical Institute.

Apparatus with sources of Co⁶⁰ γ -radiation having activities of 280 and 1440 g-equiv of radium. The principles of the apparatus and its special features. Use characteristics of the apparatus (volumes of the working spaces, average dosage intensities in the working spaces, possibilities of carrying out complex physicochemical investigations, etc.). Method of assembling powerful sources from standard commercial Co⁶⁰ preparations.

3. Study of the dosage field in the working spaces of the apparatus.

- Problems of scientific dosimetry in investigations in radiation chemistry.
- Calculation of the dosage field in working spaces of apparatus having cylindrical sources.
- Experimental study of the dosage field. Comparison of the experimental results with calculation.
- Direction of further work.

a) Increase in the specific activity of preparations; extension of the range of isotopes available for use in investigations in radiation chemistry.

b) Miniature-scale work on the configurations of sources with the object of developing methods of the highest possible reliability for the calculation of the dosage fields of powerful sources.

L. Ya. Karpov Physicochemical Institute of the Ministry of Chemical Industry of the USSR

PRODUCTION OF IMPULSE IONIZED RADIATION WITH A 1.2 Mev LINEAR-ACCELERATOR VACUUM TUBE

P. Ya. Glazunov and M. G. Kuzmin

In the course of the recent development of some fields of science associated with the study of the action of radiations on matter, a demand has arisen for new technical means for the production of very powerful sources of high-energy impulse radiation.

In the present paper a method is proposed for the production of impulses of accelerated electrons with the aid of the usual vacuum accelerator tube fed from a condenser-valve multiplier giving a p.d. of 1.3 Mv.

For the production of single impulses or a series of impulses, three schemes are used.

In the first two schemes a high-tension impulse of given form and duration is formed and applied to an electron gun.

These schemes permit the generation of impulses of electronic current of from 10 microseconds to 1 millisecond duration.

The leading and rear fronts of 10-microsecond impulses do not exceed 1.5 microseconds. The strength of the electron current in the impulse is greater than 100 ma, which, for an energy of 1 Mev, corresponds to a power of $6.25 \cdot 10^{18}$ ev for a single impulse.

The third scheme is a mechanical system—a rotating shutter. It permits the production of single impulses of up to 200 μ a and having a duration of from 10 milliseconds to 2 seconds.

Institute of Physical Chemistry of the Academy of Sciences of the USSR

USE OF SOURCES BASED ON UNSEPARATED FISSION FRAGMENTS IN RADIATION-INDUCED CHEMICAL PROCESSES

P. V. Zimakov, E. V. Volkova, and L. A. Krasnoussev

1. Sources based on unseparated fission fragments are the most promising sources of β - and γ -radiation for use in industry. This paper examined the possibility of utilizing the β - and γ -radiations of fragment sources in radiation-induced chemical processes.

2. Characterization of the first laboratory samples of irradiators based on unseparated fragments. The fragment irradiators that we use are solid concentrates prepared in different forms (cylinders, discs, granules), their activity being firmly associated with a carrier. They are mixed β - and γ -irradiators. The principal γ -irradiators present are zirconium and niobium, and the principal β -irradiators—cerium, strontium, and yttrium. The maximum energy of the β -rays is 3-3.5 Mev, and the maximum energy of the γ -rays is 0.73 Mev.

3. The use of fragment irradiators as sources of internal irradiation. When the irradiators are introduced into neutral media, such as alcohol, benzene, and acetone, no leaching of the activity is observed. For work in corrosive media, the irradiator is enclosed in a thin-walled glass envelope. In these cases both the γ - and the β -radiation is utilized, with the result that the dosage intensity is increased several times.

The dosage intensity of useful radiation from fragment irradiators depends on the geometric form of the source.

The use of β -radiation in fragment irradiators makes it possible to increase the useful life of the irradiator considerably, for the half-life of the β -sources present is greater than the half-life of the γ -sources.

4. A comparison was made of the efficiencies of sources based on unseparated fragments and sources based on radioactive cobalt in radiation-induced reactions.

The following processes were investigated: chlorination of benzene, decomposition of hydrogen peroxide, oxidation of paraffin. It was shown that, for identical doses of absorbed energy, the rate of decomposition of hydrogen peroxide, the yield of hexachlorocyclohexane in the chlorination of benzene (content of γ -isomer 15-17%), and the reduction of the induction period in the oxidation of paraffin (from 360 to 60 hours) were independent of the source of the energy (fragment irradiator or radioactive cobalt). No essential differences could be detected in the courses of these processes, in spite of difference in the distribution of ionization density created by the fragment irradiator and radioactive cobalt.

5. For the production of identical doses and absorbed energy, a considerably smaller amount of the fragment source is required than of radioactive cobalt. This simplified the problem of protection from radiation.

Owing to the comparative cheapness of fragment irradiators, their use may have a considerable economic advantage over the use of radioactive cobalt.

Research Institute of the Ministry of Chemical
Industry of the USSR

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ALL-UNION CONFERENCE ON THE APPLICATION OF
RADIOACTIVE AND STABLE ISOTOPES IN THE
NATIONAL ECONOMY AND SCIENCE

ACHIEVEMENTS OF NATIONAL SCIENCE AND INDUSTRY IN USING
RADIOACTIVE METHODS FOR PROSPECTING AND DEVELOPING
USEFUL MINERALS

V. N. Dakhnov

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Editor

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The great possibilities of radioactive methods for investigating the chemical composition and structure of materials, their high accuracy and many-sided use, the considerable prospects that existing methods will be refined and that new, more accurate modifications will be produced have determined the advantages of applying the methods of nuclear physics to the solution of numerous problems encountered in prospecting for and developing deposits of useful minerals [2].

The natural radioactivities of the uranium and thorium families have long been used very effectively in prospecting for deposits of these minerals. But the considerable differences in the content of radioactive elements in the soils of various types and mineralogical compositions, and the relations of these contents to the conditions under which the rocks were deposited makes it possible to use measurements of the natural γ -ray intensity for studying well sections composed of sedimentary rocks of low radioactivity, in particular for studying sections of oil and gas wells without taking cores.

The use of radioactive methods in geology has developed on a particularly large scale in recent years, due to the new methods of studying rocks, which are based on the use of nuclear reactions and other processes occurring when radioactive radiations act on materials, which have become available due to the vast developments in nuclear physics and measuring techniques. These achievements in nuclear physics, which occupied a comparatively short space of time - i.e., the last decade or so - have produced a number of highly effective ways of studying rocks in bore-holes without core-sampling, and radioactive isotopes and their radiations have been widely used for solving a vast number of problems in geological prospecting and technology [5, 7, 10-12].

The following are some of the methods which have been developed and introduced into various branches of industry:

a) Neutron-logging of bore-hole sections, using the moderation and subsequent absorption processes occurring with neutrons in rocks. These processes cause changes in the neutron density, in the intensity and spectra of the prompt γ -rays emitted, and in the intensity and spectra of the induced γ -activities, depending on the chemical composition of the rock.

b) Study of the γ -ray intensity scattered from a source specially inserted in the well;

c) Measurement of the γ -rays emitted by radioactive isotopes introduced into the medium.

The above methods enable one to study the geological strata in bore-holes in more detail and more accurately, and as they do not require costly core sampling, to determine the sites of mineral deposits more accurately. They also provide a means of studying the strata in lined wells in detail and of deriving more exact information about the technical state of the well.

The present communication gives a short review of the current situation as regards the industrial use of radioisotopes and their radiations in prospecting and development of useful minerals, and of the most important achievements in perfecting these methods which have been performed at the establishments of the Academy of Sciences, USSR, of the Ministries, and of the higher educational organizations. Some further ways of perfecting radiometric methods and their industrial utilization are also pointed out.

During the two years that have passed since the July meeting of the Academy of Sciences, USSR on the Peaceful Uses of Atomic Energy, the use of radioactive methods in prospecting and development of useful minerals has extended considerably, primarily due to the refinement of radiometric methods used in the oil industry, and secondly due to the wider use of these methods in prospecting for other useful minerals (additional to oil, natural gas and the radioactive elements).

The most important achievement in this field during this period is the industrial testing of the γ -ray scattering method for studying the strata in coal bore-holes.

A number of electrical methods are widely employed together at the present time for studying the strata in coal bore-holes; these have facilitated the discrimination of coal seams in bore-hole strata, the determination of their thickness and structure, and sometimes the volatile and ash contents to a certain degree. Since some coals (brown coals and transition types preceding anthracite) frequently have electrical properties very similar to those of the surrounding sediments (sandstones, dense argillites and friable limestones) the electrical methods cannot always give an unambiguous answer to the problem. This has obliged geologists to abstain from using the highly efficient coreless methods of boring.

The method in which the coal seams are detected by the intensity of the scattered γ -rays using a ^{60}Co source (which was developed by the team of workers at the Urals branch of the Academy of Sciences, USSR, directed by Bulashevich) which has been given extensive trials in the production divisions of the "Geofizizugelogeology" Trust in the Chelyabinsk, Sub-Moscow, Donetsk and Kuznets basins and in the East Urals coal formation, enables one to detect coal seams in bore-hole strata [5, 7].

The coal seams are of anomalously low density relative to the adjacent rocks. The densities of coal seams vary over the range 1.1 - 1.6 g/cm^3 , rising with the rank of the coal and the ash content: they are about one unit less dense than the adjacent rocks (argillites, siltstones, sandstones and limestones). This results in exceptionally favorable conditions for using γ -ray scattering methods for detecting coal seams in bore-holes.

With an appropriate distance between primary γ -ray sources and scattered γ -ray detectors the coal seams stand out clearly as maxima on the scattered γ -ray intensity traces (Fig. 1, curve 5; Fig. 2, curve 2). When combined with cavity and electrical measurements it enables one to detect the coal seams unambiguously and even to study their structures via the electrical data.

The work so far carried out should only be considered as a preliminary but highly effective experiment on the use of radiometric methods for studying coal bore-hole strata. There is no doubt that when a whole number of radiation methods are used together it will be possible to study coal seams in more detail - as to their volatile and ash contents.

Ryapolova's work (carried out at the Ministry of Transport Construction) has demonstrated the efficacy of radiation methods in the study of water bore-hole strata. The detection of rocks saturated with fresh water from geophysical data is often a fairly complicated problem, since the water-bearing rocks differ little in electrical properties from adjacent ones. The prospector frequently encounters the need to detect water-bearing rocks in carbonate strata and the difficulties here are greatest. An experiment on the use of radiation methods for studying water bore-hole strata has shown that measurements of the natural γ -ray intensities and the prompt γ -rays from neutron absorption enable one both to increase the accuracy with which water-bearing rocks are detected and also to estimate their probable yields in some cases. The latter is of great practical interest in the choice of those to be utilized. Radiation methods are also of great practical interest in that more promising horizons can sometimes be detected in old lined wells, thus providing increased well output and extended life.

As has been noted above, the industrial use and further refinement of radiation methods has occurred on a particularly large scale in the oil industry, the aim being the study of the geological structures and technical states of wells. The volume of radiation studies carried out by the Glavneftegeofizika* Undertaking of the USSR Ministry of the Oil Industry reached 7 million meters of bore-hole strata in 1956, some 150 industrial groups operating in this field.

The results from the use of radiation methods in oil and natural gas prospecting were mainly as follows:

1. These methods raised the efficiency of coreless boring in the carbonate and hydrochemical deposits of the Volga-Urals oil province considerably, ensured their correct delineation in the carbonate and hydrochemical deposits, and facilitated the detection of increased porosity and permeability in carbonate sediments, which latter are promising as regards possible oil/gas content.
2. Radiation methods ensure much more exact differentiation of bore-hole strata which have complex rocks of high resistance when the boring is carried out with strong salt solutions. Under these conditions the standard electrical methods are of little value.
3. Radiometric and electrometric methods, when combined, enabled one to discern the gas-bearing strata in bore-holes quite clearly for a number of areas in the Volga-Urals oil province, and in the deposits of the North Caucasus and the Western Ukraine (Fig. 3, curve 1). In most cases this was impossible by the use of electrical

* Glavneftegeofizika = Main Administration for Geophysics - Translator.

logs alone. Accurate determination of the gas/oil contact ensured that the correct choice of usable strata was made and that development was correct.

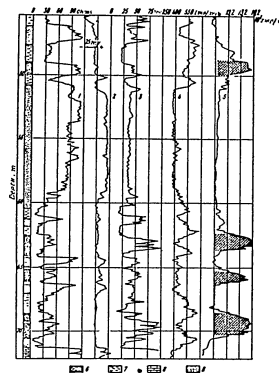


Fig. 1. An example of the detection of coal seams by γ -ray scattering (Moscow coal basin). 1) apparent resistance curve; 2) inherent polarization potentials; 3) induced polarization potentials; 4) natural γ -ray intensity curve; 5) scattered γ -ray intensity curve; 6) coal; 7) clay; 8) limestone; 9) sand.

The coals are clearly detected from the scattered γ -ray intensity maxima (cross-hatched areas).

4. An important contribution was made to the practical use of radiometry by the development of neutron methods for differentiating oil-bearing strata from water-bearing: this was first performed by the group in the Radiometry Laboratory of the Gubkin Oil Institute, Moscow (A. I. Kholina, O. A. Barsukov, et al.). These methods facilitate the wide use of radiometric logging in research on the opening up of oil deposits which are exploited by contour water-pumping [12]. This method uses the difference in the chlorine contents of oil and water-bearing strata to solve this problem, neutron methods being used, since chlorine is one of the basic components of salt water; use is thus made of its specific nuclear properties. The neutron absorption cross-section of chlorine (32 barns) exceeds that of the other main elements present in the rocks of oil deposits very greatly, there having cross sections of 0.0002 - 0.5 barn. Neutron absorption by chlorine gives an increased prompt γ -ray intensity and a change in its spectral composition. Thus with appropriate well preparation the oil-bearing strata can be distinguished from the water-bearing by the reduced thermal neutron density and by the increased prompt γ -ray

intensity (Fig. 4, curves 3 and 4), particularly in the regions below 2 Mev and above 4 Mev (Fig. 5, curves 5 and 6).

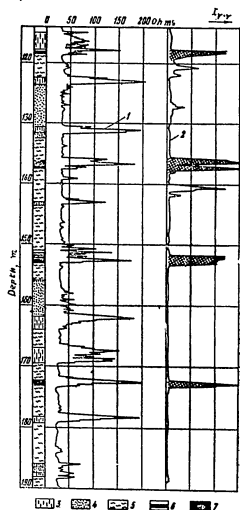


Fig. 2. An example of the detection of coal seams by γ -ray scattering (Chelyabinsk coal basin). 1) apparent resistance curve; 2) scattered γ -ray intensity curve; 3) dense sandstone; 4) friable sandstone; 5) argillite; 6) argillite and coal; 7) coal. The coals are clearly detected from the scattered γ -ray intensity maxima (cross-hatched areas).

problems such as the detection of fissures in the hydraulic disruption of strata by pumping activated sand into the fissures (Fig. 8). Clear results were also obtained when boring wells with active solutions. In this case the fact that the boring solution penetrates deeper into porous and permeable rocks makes it possible to detect them. Analysis of the data gave quantitative relations between the rock porosity and the observed γ -ray intensity. This method is of particular interest for detecting fissured zones in carbonate rocks, this being in the majority of cases impossible when other geophysical methods are used.

In order to use the various isotopes in a scientific fashion in well-logging, A. A. Korzhnev and others (All-Union Geophysics Research Institute) have studied their sorption on rocks. They showed, in particular, that cesium was the most adsorbed, and iron and iodine the least.

When these methods were used in deposits where the strata waters were highly mineralized it was possible to establish the way water moved during contour water-pumping (Fig. 6) in important areas such as Tuimazinsk and Bavlinsk. This would be impossible by other methods without drilling an enormous number of test bore-holes.

To differentiate oil and water when the strata waters contain relatively little chloride (e. g., when the waters are alkaline) the team directed by F. A. Alekseev at the Academy of Sciences, USSR Oil Institute developed a method of differentiating oil-bearing rocks from water-bearing which uses sodium activation [10]. The trial groups of the "Tauftegeofizika" trusts showed that this method could be made more accurate by using thermal neutron activation of manganese, the manganese being present in the metal of the bore-hole liner, the thermal neutron densities being higher in the oil-bearing strata than in the water-bearing ones.

5. The use of radioactive isotopes increased the accuracy with which the technical states of wells can be studied, e.g., determination of the height to which the mortar has risen around the liner and the quality of the cementation, detection of areas where water circulates around the tube or points of damage to the liners and determination of zones where the boring solution has penetrated [6, 11]. In this connection a special mention must be made of the work carried out under the direction of G. N. Strotsky ("Grozneftefizika" Trust) which was directed to improvement of methods for using radioactive isotopes to study the technical states of wells. In particular the "Grozneftefizika" Trust has produced bore-hole radioactive isotope injectors which have allowed the work to be carried out much more rapidly with isotopes and which have much reduced the radiation hazard to the operating personnel. For example, Fig. 7 shows the detection of a flow in the cement around a liner, using the injector.

Isotopes have found a wider use in solving complex problems such as the detection of fissures in the hydraulic disruption of strata by pumping activated sand into the fissures (Fig. 8). Clear results were also obtained when boring wells with active solutions. In this case the fact that the boring solution penetrates deeper into porous and permeable rocks makes it possible to detect them. Analysis of the data gave quantitative relations between the rock porosity and the observed γ -ray intensity. This method is of particular interest for detecting fissured zones in carbonate rocks, this being in the majority of cases impossible when other geophysical methods are used.

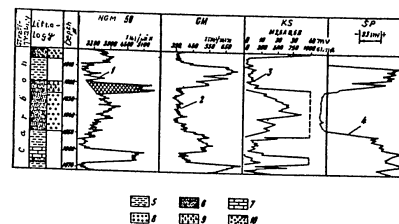


Fig. 3. Detection of the gas-bearing part of a stratum using the (n, γ) method. 1) (n, γ) intensity curve (NGM - 50); 2) natural γ -ray curve (GM); 3) apparent resistance curve (KS) (probe M, 2.5 A 0.5 v); 4) inherent polarization potential (SP); 5) clay; 6) sandstone; 7) limestone; 8) oil; 9) gas; 10) water.

The gas-bearing part of the stratum (detected from the inherent polarization potential) is distinguished by a sharp rise in the (n, γ) curve (cross-hatched area).

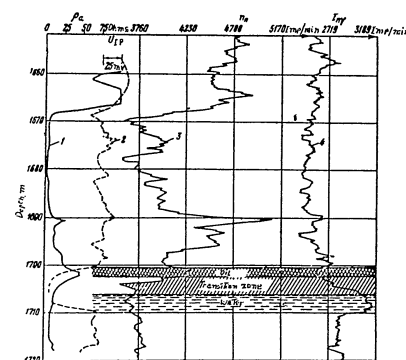


Fig. 4. An example of the determination of the water/oil contact by combining (n, n) and (n, γ) methods.

1) Apparent resistance curve σ_a (probe B, 7.5 A 0.75M); 2) inherent polarization potential, U_p ; 3) (n, n) curve, n_n ; 4) $I_{n\lambda}$ curve (prompt γ -rays). The water-bearing part of the stratum is distinguished by a sharp drop in n_n while $I_{n\lambda}$ is raised.

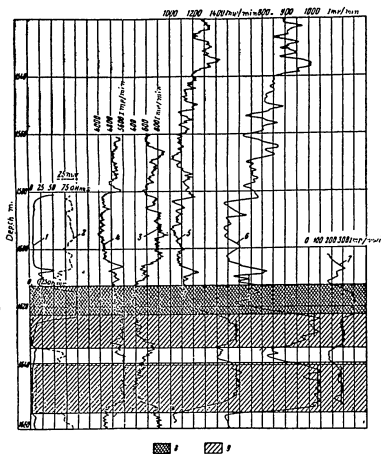


Fig. 5. An example of the determination of an oil/water contact: 1) apparent resistance curve (probe B, 7.5A 0.75M); 2) inherent polarization potential; 3) natural γ -ray intensity; 4) intensity from (n, γ) log (probe length $L_n = 60$ cm); 5) intensity from (n, γ) log (spectroscopic method $L_n = 33$ cm); 6) the same ($L_n = 38$ cm); 7) thermal neutron density; 8) oil-bearing sandstone; 9) water-bearing sandstone.

The use of radioactive methods for research on oil and gas wells has led to multimillion ruble economies in materials due to the more exact identification of geological strata in bore-holes, to the detection of oil and gas beds, to the improvement in means of checking up on the development process in the fields, and to the elimination of large losses due to unproductive work in unjustified maintenance.

Very much less progress has been made in using radioactive methods for locating and developing useful ore-minerals [7]. In spite of the demonstration by A. P. Ochikura, et al. (All-Union Institute of Prospecting Geophysics) that in principle it is possible to detect ore-inclusions from data on γ -ray scattering, the method has, so far, not been widely used in practice. The neutron methods for detecting boron-containing rocks which have been developed under the direction of A. P. Vinogradov and V. I. Baranov (Vernadsky Institute of Geochemistry and Analytical Chemistry), with the cooperation of the Gubkin Oil Institute, Moscow, have given good results with wells in Eastern Siberia, but they have not been utilized. Little attention has been paid to the use of induced activity for work on the chemical compositions of ore inclusions, primarily for locating and developing bauxite and for the detailed study of bore-hole strata in regions of sulfide ore orogenesis.

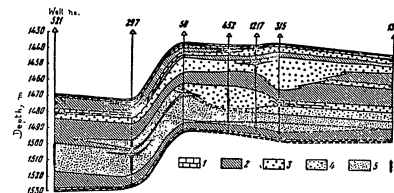


Fig. 6. An example of the detection of a water/oil contact during opening up, radiometric logging being used. 1) limestone; 2) clay; 3) oil-bearing sandstone; 4) transition zone; 5) water-bearing sandstone; 6) region of liner perforation.

A number of researches have shown that it is possible to use γ -ray methods for detecting bauxites, which differ by their high radioactivities, and for detecting calcium salts in bore-holes and complex evaporite deposits, but these cannot be considered as of adequate importance as regards the use of radiation methods for finding useful minerals. The testing and introduction of radiation methods for detecting ore deposits leaves much to be desired. The Ministry of Geology and Conservation of Mineral Resources, USSR must, in our opinion, be primarily held responsible for this, as having not devoted the requisite attention, and not having circulated the results which have been obtained to a wide circle of workers in the geological service.

The results from using radioactive methods in the oil industry and the commencement of their effective introduction into the coal industry cannot be considered in isolation from the results carried out in the radiometry laboratories of the Academy of Sciences, USSR Oil Institute, of the Urals branch of the Academy of Sciences, USSR of the All-Union Geophysics Research Institute, and of the Gubkin Oil Institute, Moscow. The scientific teams in these institutes and the study groups of the divisions in the Ministry of the Oil Industry have carried out the following research during recent years.

The γ -ray scattering processes in rocks have been studied analytically (G. M. Voskoboinikov, I. G. Dyadkin, et al.); also the neutron distributions in oil and water-collecting strata pierced by a bore-hole (S. A. Kantor and O. A. Barsukov).

Some of these problems, which are very difficult to solve by mathematical methods, have been studied by analog methods at the Volga-Urals branch of the All-Union Geophysics Research Institute and at the Gubkin Oil Institute, Moscow. This work has particularly demonstrated the effects due to fresh-water infiltration zones produced by the boring solutions on the prompt γ -rays from radiative neutron capture in lined and unlined wells, and the optimum conditions for carrying out measurements designed to detect the oil/water contact have been determined.

The work carried out at the Volga-Urals branch of the All-Union Geophysics Research Institute (Yu. A. Gulin) and in the radiometry laboratory of the central division in Moscow has shown that it is possible to study the densities and porosities of rocks from data on scattered γ -ray intensities.

The distributions of epithermal neutrons have been studied at the Volga-Urals branch of the All-Union Geophysics Research Institute, the Gubkin Oil Institute, Moscow, and the Moscow Oil Institute. This work confirmed that it was possible to determine rock porosities more accurately by recording epithermal neutron densities, and has also elucidated the role of epithermal neutron absorption by chlorine in differentiating water and oil-bearing strata by the (n, γ) method.

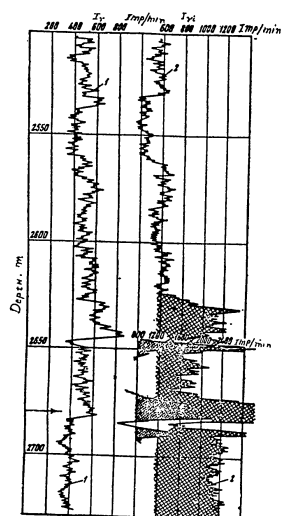


Fig. 7. An example of the determination of the site of a flow in the cement around a liner by injecting a radioactive solution.

1) Natural γ -ray intensity I_n ; 2) γ -ray intensity I_γ after injecting the active solution and pumping it around the column. The injection was made at 2680 m depth (shown by the arrow). The flaws in the cement are shown cross-hatched.

b) Units for operating at high temperatures in wells (All-Union Geophysics Research Institute, "Grozneftegeofizika" Trust from which qualitative diagrams have been obtained on working in bore-holes at rock temperatures up to +150°C.

c) Scintillation counter units (developed by the All-Union Geophysics Institute in conjunction with the "Oil Equipment" factory and the Academy of Sciences, USSR Oil Institute), these having advantages over the earlier units using gas-discharge counters as regards count rate and wider control over their spectral sensitivities.

The scintillation units produced by the "Oil Equipment" factory for recording thermal neutrons were built using neutron-sensitive phosphors.

Much attention has been devoted to improving the accuracy with which the results from radiometric logs are interpreted. To this end the radiometry laboratory of the All-Union Geophysics Research Institute (directed by V. M. Zaporozhnyi) has developed methods of calibrating units used for recording natural γ -ray intensities in bore-holes in air units and for those used to record neutron capture γ -rays in arbitrary units based on surrounding the unit with water. Nomograms were also developed from which the rate of recording required to ensure the requisite degree of accuracy could be read off.

Further work on a method of determining rock densities has also been undertaken. The (n, γ) method was reconsidered as it had been shown that chlorine has a marked distorting influence.

Work on this topic has shown that the exponentially diminishing relation of capture γ -ray intensity to rock porosity found earlier is only observed in rocks which contain no strong absorbers; when the chlorine content is high the relation of capture γ -ray intensity to rock porosity is linear. This explains the source of considerable errors in the rock porosities found by earlier methods, and reveals new and more accurate ways of determining rock porosity.

The newly developed methods provide a means of determining rock porosities from epithermal neutron densities, these being only slightly affected by the chemical composition.

Much attention has been devoted to developing new types of radiometric well-logging equipment. The following new units should be noted:

a) logging units using proportional neutron counters for recording thermal neutron densities (Academy of Sciences, USSR Oil Institute and Gubkin Oil Institute, Moscow). Industrial tests of these units have confirmed the advantages of the (n, n) method for work on the storage properties of strata, and the detection of oil-bearing strata has been facilitated by thermal neutron density measurements.

b) Units for operating at high temperatures in wells (All-Union Geophysics Research Institute, "Grozneftegeofizika" Trust from which qualitative diagrams have been obtained on working in bore-holes at rock temperatures up to +150°C.

The scintillation units produced by the "Oil Equipment" factory for recording thermal neutrons were built using neutron-sensitive phosphors.

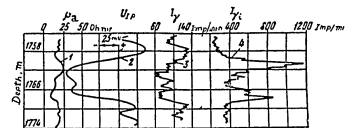


Fig. 8. An example of the use of radioactive isotopes for determining the sites of water-fissuring in strata.

1) Apparent resistance curve, ρ_a (probe B7.5A 0.75M); 2) inherent polarization potential, Up; 3) I_n natural γ -ray intensity; 4) I_γ , γ -ray intensity curve after hydraulic destruction and injection of activated sand.

d) A two-channel unit using boron screening (Gubkin Oil Institute, Moscow) for determining water/oil contacts and for carrying out lateral (n, γ) sounding, etc.

The Machine Operation and Automation Institute of the Ukrainian Academy of Sciences has produced a 4-channel unit for measuring the natural γ -ray intensity, the neutron capture γ -rays with two sizes of probe, and the thermal neutron density, simultaneously, using one single-core cable.

The most important trend in the development of radiometric equipment is the design of small neutron generators for well-logging. Such units are at present produced in the USA and have great advantages over polonium-beryllium and other similar neutron sources.

As well as being widely used for studying bore-hole strata and the technical states of wells, these methods are used for prospecting for useful minerals on the surface.

For example, they were used successfully on the eastern side of the Kuznets Ala-Tau for delineating eruptive rocks buried under intrusive deposits and for detecting zones of tectonic faulting.

F. A. Alekseev, at the Academy of Sciences, USSR Oil Institute, has directed work on radiation methods of detecting oil deposits from the surface [1]. The field groups from the Institute found that the natural γ -ray intensity was often reduced over oil deposits, there being rings of raised activity at the peripheries. Analogous results were obtained by the "Bashmeftegeofizika" Trust for oil deposits.

The physical basis of the method is not clear. It may be that the observed effects are due to changes in the lithology of the surface deposits in the vaulted areas of the structure, but the authors still consider that a direct relation between the γ -ray intensity changes and the oil deposits should be sought. The Academy of Sciences, USSR Oil Institute has designed field radiometers for continuous recording of γ -ray intensities from surface vehicles and aeroplanes.

Radiometric methods have also been successfully tested in other branches of mining. For example, G. I. Pokrovsky and A. A. Chernigovsky (Zhukov Air Force Engineering Academy) have shown that it is possible to use radioactive isotopes for work on soil displacement in explosions. A. D. Godroshko, et al. (Academy of Sciences, USSR, Institute of Fuel Resources) have worked on the design of units for coal enrichment using the γ -ray absorption of the material. Similar work has been carried out in other research Institutes.

To sum up, we must observe that the use of radiation techniques has extended considerably in the last two years as regards the location and development of useful mineral deposits.

However, the present successes do not exhaust the vast possibilities of radiation methods and we must particularly point out that there are still a large number of un-solved problems in both the use and refinement of radiometric methods.

First, we must once again emphasize the need for the wide use of radiometry in locating and detecting ore

deposits, particularly with regard to deposits of boron, manganese, mercury and aluminum. For example, the exceptionally high capture cross section of boron for thermal neutrons would enable one to detect it reliably by neutron methods in rocks containing 0.25% B or more, or even less than this under some conditions.

The chances of detecting manganese are also very good, due to its high capture cross section (12.7 barns), high prompt γ -ray energy (up to 7.3 Mev), high activation cross section (12.7 barns) and relatively short half-life (2.6 hours). Thus manganese could be detected by neutron absorption, (n, γ) and induced activity.

The high capture cross sections of mercury (380 barns), tungsten (19.2 barns), cesium (29.0 barns) and particularly of some of the lanthanide elements (samarium, europium, gadolinium, dysprosium) gives promise of success in developing ways of detecting rocks enriched in these elements. When setting about this work attention must be paid to all the nuclear properties of these elements.

The short half-life of aluminum (2.3 minutes) and the fairly high activation cross section (0.21 barn) make prospecting for bauxite and determination of the aluminum contents of bauxite by induced activity methods very promising.

When sulfides are studied by induced activity methods it will evidently be possible to detect copper (Cu^{64} and Cu^{65} , half-lives 12.9 hours and 5.3 minutes, respectively) nickel (2.8 hours) etc. For this purpose γ -ray spectroscopy must be used to the full extent.

To increase the certainty of work with ore bore-holes, existing methods must be widely tested and used, but work on new methods must proceed at the same time, particularly with γ -ray measurements, when the bore-hole walls are bombarded by high-energy neutrons, photoneutron methods and resonance absorption of neutrons in rocks.

Radiation methods should also be widely used in surface prospecting for useful minerals and in geological mapping, e.g., for delineating various types of intrusion, detection of tectonic fault zones, etc., for which purpose equipment of high sensitivity must be used.

When radiation methods are given extended use in coal bore-holes attention must be paid to the determination of ash contents; this can probably be done by coal seam density measurements based on γ -ray scattering and on silicon content measurements (from the intensity of the hard component of the prompt γ -rays). Much attention should be paid to γ -ray scattering, (n, n) and γ -ray spectroscopic methods in work with oil and gas wells. These methods enable one to identify the rocks more accurately and to study the porosity and oil and gas saturations.

When radioactive isotopes are used, much attention must be devoted to short-lived isotopes with half-lives from 1 to 20 days. Centers where these isotopes are prepared continuously should be organized in the southern and eastern oil-bearing regions. When work is carried out with hydrogeological bore-holes the greatest attention should be given to γ -ray scattering methods for detecting highly porous rocks, which are of reduced density, of course; and to the use of short-lived radioactive isotopes for detecting fissured zones. Concerning the further refinement of equipment, there is the need to produce units of higher sensitivity for well-logging to detect γ -rays and neutrons of various energies, which are designed to operate at temperatures up to 150 - 200°C. Industry must provide much help in the development of these units by producing electronic components and special cables designed for operation under the above conditions. Particular attention must be paid to quicken possible production of well-logging neutron generators and betatrons designed to give powerful monoenergetic sources. These will raise the accuracy considerably and extend the range of problems which can be solved by radiometry.

When questions of interpretation of the results from radiation measurements are dealt with, much attention must be given to more efficient ways of determining porosities and oil- and gas-saturations as well as to methods of determining the chemical compositions of rocks quantitatively. Radiometric and other geophysical methods will have to be used extensively to solve these problems.

Activation analysis is of particular interest, in that it is the most exact way of studying the chemical compositions of rocks.

More attention will also have to be devoted to the more accurate determination of absolute ages of rocks, particularly with the object of deciding on the genesis of useful mineral deposits more precisely.

Solutions of the above problems will raise the efficiency of location and development of useful minerals and will produce conditions favorable to the still wider use of radiation methods in the mining industry.

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NATIONAL ECONOMY AND SCIENCE

USE OF NUCLEAR RADIATION FOR AUTOMATION AND
TECHNOLOGICAL PROCESS CONTROL IN THE USSR

N. N. Shumilovsky and L. V. Meltser

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According to the directives of the 20th Party Congress [1], an increase in production by means of automatic devices has been recognized as a problem of the first rank; the necessity for developing every possible application of radioactive materials in the control and automatic regulation of production processes is especially emphasized.

Technological progress in industry and, in particular, in the automation of production processes has been accompanied by a rather considerable increase in the requirements on the methods and techniques of automatic control. The requirements with regard to speed of operation, sensitivity, and accuracy have been made more stringent, and at the same time the field of application of automatic-control methods for obtaining more complete and accurate information on the process being controlled, has been extended.

The use of nuclear radiation yields the possibility of widening considerably the region of application of automatic-control methods and also offers new solutions for problems which arise in automation. In this connection, nuclear radiation has a number of advantages in measurement technique (non-contact properties, absence of any effect due to external conditions on the radiation source, absence of any interaction effects between the medium being controlled and the measurement device, high stability and duty capabilities of radiation sources, quick operation, etc.).

All control techniques may be divided into three groups, based on the feasibility of using a given control method (with or without the use of nuclear radiation). The first group pertains to cases in which only radioisotopes can be used to control a given process to avoid disturbing the process itself. Examples of this situation are measurements of the thickness of a non-magnetic plating material on a non-magnetic base, non-contact measurements of thickness and weight of moving material, location of damage in underground conduits, etc. In these cases, the use of radioisotopes is definitely indicated, without regard to expense, since no other means is feasible.

In the second group we include processes which can also be controlled by other methods. However in these cases the use of radioisotope methods may make it possible to solve certain problems more simply and conveniently, and hence should be given preference.

The third group includes all processes which can be controlled in a simpler way by the usual methods, i. e., without the use of radioisotopes.

Turning to a survey of the basic trends in the development of automatic control using nuclear radiation, we may note that certain approaches have already become well established. Typical examples of these are methods which exploit the effects of absorption and scattering of radiation in the material being controlled, the effect of ionization in a material being irradiated, and so forth. These methods have found application in various branches of industry and one of the basic present-day problems is the further improvement and development of these methods and initiation of large-scale production of appropriate devices (also the development of new techniques and devices).

It should be pointed out that even though the number of newly developed methods in this field and the new experimental techniques do not lag, and may even surpass those of foreign countries, the introduction and industrial acceptance of devices of this kind lag far behind that which is found abroad. One redeeming factor,

however, is the theoretical work which has been carried out in the field of measurement techniques [8-10]. This research has furthered the work on the development of methods and devices and has created a theory and given methods of engineering calculation for nuclear-radiation devices so that the design and development of these systems can be carried out in a scientific and rational way.

Along with the trends which have been mentioned above, there are a number of other approaches which, while well-known to physicists, have still not received wide development in the field of measurement technique. Here we refer to the use of nuclear spectroscopy, neutron fluxes, certain nuclear reactions and a number of other phenomena for control of technological processing which are well-known in present day physics. These methods of control are especially desirable since, in a number of cases, they could yield solutions to such important problems as the automatic, continuous non-contact control of the composition of complex materials. We now consider, in somewhat greater detail, each of the approaches which has been mentioned above.

1. Use of the Penetrating Properties of Radiation and Measurement of Absorption and Back-Scattering in the Material Being Controlled

This method has, at the present time, been used more than any other.

As is well-known, the absorption of β - and γ -radiation in a material is given, with rather good accuracy, by an exponential law.

$$J = J_0 e^{-\mu d} = J_0 e^{-[\mu_m d] \rho} = J_0 e^{-\mu p} \quad (1)$$

where J_0 is the intensity of the radiation flux incident on the absorber; J is the intensity of the radiation flux which passes through a layer of absorber of thickness d (cm) and density ρ (g/cm³); μ is the coefficient of linear absorption in cm; $\mu_m = \mu/\rho$ is the coefficient for mass absorption, cm²/g; $p = \rho d$ is the weight of the absorber, referred to a unit area, g/cm².

From Equation (1) follows directly the possibility of determining density, thickness, and weight of an irradiated material. In turn it is also possible, using the difference in the density of the absorber medium, to obtain information on solid-impurity content and so forth.

In a number of cases (measurement of the thickness of plating, concentration of material, etc.) it is possible to use effects associated with back-scattering of β -radiation in the material. The strength of the scattering of the β -radiation in the backward direction is a function of the atomic number of the scatterer and is approximately given by a Z^2 -law where Z is less than unity and depends on the experimental geometry.

The operating principles of devices in which use is made of radiation absorption are extremely varied. In certain cases (for example, in measuring density, thickness, and weight) the values of the parameters to be determined are obtained from the amount of absorption in the material being controlled. In other cases, in which "relay" operation is used, it is important only to establish the fact that radiation is incident on a detector. In this case, the detector and the radiation source may be moved with respect to each other or with respect to an object which passes between them and blocks the radiation path. Finally, there are cases in which it is not necessary to establish the presence of radiation or the amount of absorption, for example, in determining the frequency of alternation between various states in which the amount of absorption differs (non-contact tachometer, counting of objects, etc.).

At the present time, devices which measure the amount of absorption or back-scattering are used in various branches of industry.

In the metallurgical industry use is made of non-contact control and regulation of the level of a metal, for example, in a crystallizer for continuous pouring of steel [11]. A diagram of the regulator of the steel level in a RU-2 crystallizer developed at the All-Union Scientific Research Institute for Ferrous Metals is shown in Fig. 1. A good deal of work has been carried out on the use of devices for controlling the thickness of rolled iron and the thickness of plating [12]; these devices were developed at the Central Laboratory for Automation of the Ministry of Ferrous Metallurgy in conjunction with the P. N. Lebedev Institute of Physics of the Academy of Sciences, USSR.

On the basis of incomplete data, it has been found that the application of devices for controlling the thickness of rolled iron at the V. M. Molotov Steel-Rolling Plant in Leningrad and the "Zaporozhstal" plant has reduced the rejection rate for metal thickness by a factor of two and has reduced the outage time by a factor of ten. The instruments themselves have been improved considerably while in use. Radioactive marking of rolled-iron has also been successfully carried out at the V. M. Molotov Steel-Rolling plant in Leningrad. The results obtained at this plant indicate that the application of radioactive marking yields considerable economies.

A number of original devices for the control of the level of ore and the density of pulp in non-ferrous metallurgy have been developed. In the device which is used to control ore level [13], use is made of a scintillation counter and a pulsed photomultiplier voltage supply. The use of this system has made it possible to reduce by a factor of ten the activity required of the Co⁶⁰ source; also it performs satisfactorily without special dc-ac converters. A diagram of the level-measuring instrument in the channel of an underground bunker is shown in Fig. 2.

Special attention is merited by an instrument with a vibrating radiator for controlling pulp density [14] in which the radiation is modulated. An external view of this device is shown in Fig. 3.

The application of γ -radiation for quality control of manufactured goods is one of the most important ways in which nuclear radiation is utilized. At the present time more than 1000 instruments for γ -defectoscopy of materials are being used in the Soviet Union.

The control and inspection of welded and cast parts by means of γ -rays is obligatory according to present regulations on boiler inspection and the technical requirements of many ministries and departments.

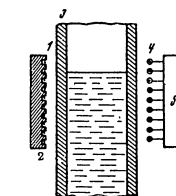


Fig. 1. Schematic diagram of the RU-2 level regulator: 1) γ -radiation source; 2) shielded container with collimating holes; 3) crystallizer; 4) counters; 5) thyatron-relay control circuit.

In recent years the "Morozenov" plant has developed several types of γ -devices for industrial radioscopes. Many new devices have been built directly in plants themselves, for example, in the shipbuilding industry.

Methods of γ -defectoscopy for welded joints and castings have been developed at the Scientific Research Institutes. In the research which has been carried out on photographic γ -defectoscopy, the sensitivity of the method for delineating minimal defects as a function of γ -ray energy has been established. Regions of application for γ -rays from the isotopes Co⁶⁰, Cs¹³⁷, Ir¹⁹², Eu¹⁵²⁻¹⁵⁴, Tl²⁰⁸ and other γ -radiators have been established.

Recent work has been done on problems of radioscopes, including methods of improving resolution of defect images on γ -pictures [15]. A method has been developed [16] for radiography of welded seams in tubes which makes use of γ -rays from the isotopes Co⁶⁰, Cs¹³⁷, Ir¹⁹², Eu¹⁵²⁻¹⁵⁴ and Tl²⁰⁸ and studies have been carried out on the application of the stopping of x-rays from the β -radiation of Tl²⁰⁸. This work has shown that using interchangeable targets it may be possible to obtain from the β -radiation of Tl²⁰⁸, x-rays with energies from 65-32 keV. Special prototype devices have been developed to investigate the use of this radiation in defectoscopy of light alloys of aluminum, magnesium and titanium.

Studies have also been carried out on the sensitivity to defects in different metals in radioscopes using γ -radiation from Tl²⁰⁸ [17] and the sensitivity of photographic methods of γ -defectoscopy using isotopes with different γ -energy [18].

The application of γ -defectoscopy on a large scale in the national economy has made it necessary to find methods for automatic γ -control of products. One of these methods involves the use of a scintillation counter in an ionization scheme. Considerable progress has been achieved in this field [19, 20, 21].

Methods of automatic γ -defectoscopy in which use is made of electron-optics and television methods appear to have great potentialities and can widen considerably the possibilities for product quality control. Work carried on in this direction by Corresponding Member, Academy of Sciences, USSR P. V. Timofeev indicates the possibility of considerable improvement (by several orders of magnitude) in the sensitivity of defectoscopes.

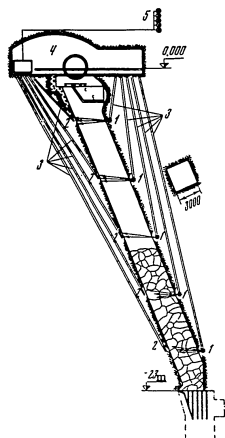


Fig. 2. Diagram of installation for measuring the level in a "non-ferrous automatic installation" in the channel of an underground bunker: 1) γ -radiation source Co^{60} ; 2) radiation detector; 3) channels; 4) measurement unit; 5) indicator.

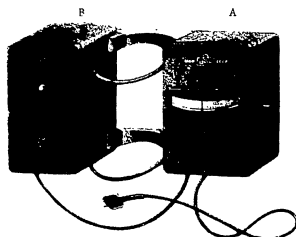


Fig. 3. External view of the densitometer with vibrating radiators; unit A contains the radiation detector and the comparison circuit; unit B contains the main radiation source, the amplifier and the power supply; the pulp pipe line being irradiated is positioned between units A and B.

The coal mining industry has developed and introduced the use of a γ -relay [22] which is used to count carts and to control the filling operation (Fig. 4), to realize non-contact foot-pedal control of an electric locomotive, automatic stopping of the train at a red signal light, as well as a number of other measurement and control operations (Fig. 5). In Fig. 6 is shown an external view of the γ -relay developed at the "Red Metallurgist" plant for automatic control in the coal mining industry.

Work has been carried out [23, 24] on the attenuation of γ -radiation by different isotopes in coal and rock. The results of this research have been used in building a prototype radiation separator which is intended for automatic separation of lumps of coal and rock which differ both in size and density. At the same time a method has been developed and used under laboratory conditions for determining rapidly the contents of mineral impurities in coal (in particular, the ash content of coal).

In the petroleum industry, devices which use nuclear radiation have been used, for example, to control the level of petroleum products [25] or to determine the position of the boundary between two materials in a covered reservoir.

Under the direction of Yu. S. Zaslavsky, a group of engineers have developed the ARTTU-2 regulator for automatically maintaining the kerosene-water boundary in the water-kerosene rinsing column of a cracking system. The regulator consists of a γ -relay and a pneumatic relay which controls the water-outlet valve for the column. Great interest for the petroleum industry attaches to the realization of automatic control for the sequential

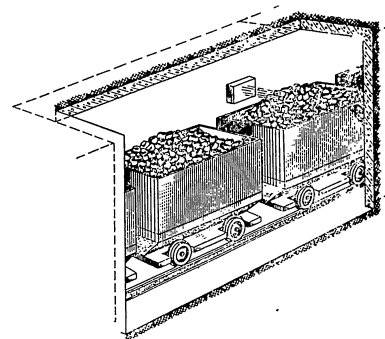


Fig. 4. Application of a γ -relay for controlling the filling of coal carts.

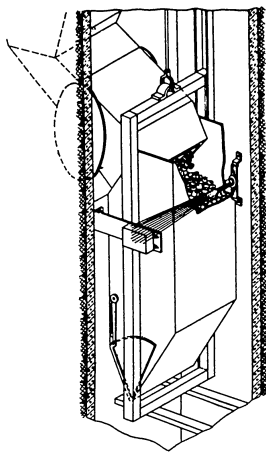
transfer of petroleum products through pipelines. Work in this field is proceeding in two directions. An experiment on an industrial scale has been carried out [26] on the sequential transfer of petroleum products over the line from Grozny to Trudovaya (887 km) in which the dividing line was marked by triphenylstibine containing radioactive Sb^{124} . The results of this work were more or less positive although the method has one important shortcoming in that radioactive materials are introduced into the petroleum products.

The other approach being explored by Yu. S. Zaslavsky et al. involves density control of the products which pass through the pipelines, through the absorption of γ -radiation in these materials. This method has many potentialities; however, there is a great deal of difficulty from the point of view of the measuring technique itself since the requirements on the accuracy in controlling the density of petroleum products are better than 0.1 %.

In the textile industry instruments are used to control the uniformity of product and the weight of moving fabric [27]. In Fig. 7 is shown a schematic diagram of a device for measuring and recording the uniformity of products from a spinning machine. The device makes use of a differential measurement scheme and provision is made for automatic computation of the variation factor.

The devices for automatic control of the weight of moving fabric use a comparison scheme. An external view of a data-pickup element for such a device is shown in Fig. 8. Two versions of the instrument have been constructed. In the first a Tl^{204} radiator is used, in the second a Sr^{90} radiator is used. The measurement range of the first instrument is 150-800 g/m², that of the second is 800-5000 g/m². Ionization chambers are used to detect the radiation. The uncertainty in a weight measurement is not greater than 1%. At the Nogli factory the use of an instrument for controlling fabric weight has made it possible to save a great deal of fabric.

Other work is being carried on; for example, apparatus is presently being developed and tested for automatic control of the operation of a disintegrator which employs a radioactive transducer.

Fig. 5. Application of a γ -relay in a filling device.

In the paper manufacturing industry a "Goznak Weight Meter" has been developed [28]; this machine allows the continuous automatic control of the weight of paper and makes use of the absorption of β -radiation in the paper. It is convenient to express the weight of the paper in terms of a unit of area of a sheet, which is given in g/cm^2 or g/m^2 .

Work has been carried out to study the errors which arise due to changes in the position of the material in the gap between the radiation source and pick-up device. It has been found that by setting up a collimating grid in the radiation path and increasing the area of the source, this error can be reduced considerably. The "Goznak Weight Meter" (Fig. 9) makes use of the comparison principle through a differential system of ionization chambers, a "dynamic" variable condenser and a "profile slide-wire" recorder which provide high accuracy and good measurement sensitivity and a fairly linear scale. The radiation source is Ti^{54} . The uncertainty in a weight determination is less than 1%.

In the fur industry a radiation "thickness" meter has been developed [29] which makes possible the continuous automatic control of fur thickness by the absorption of β -particles without damage to the fur itself. A diagram of the measurement scheme is shown in Fig. 10.

In the tanning industry a method has been developed for controlling the thickness of skins [30] by the absorption of γ -radiation from Ce^{144} . The instrument makes use of a very simple comparison scheme (Fig. 11) in which the comparison source is placed on the needle of the indicating instrument. The radiation detectors are halogen counters in which the average current is measured.

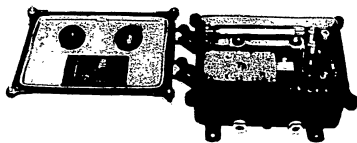
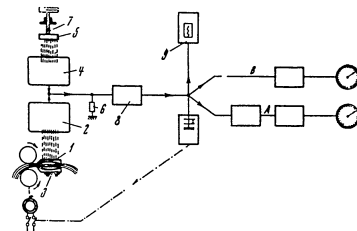
Fig. 6. External view of the γ -relay GERN-3.

Fig. 7. Schematic diagram of an instrument for measuring and recording non-uniformity of products in the spinning industry: A) squaring integration channel; B) linear integration channel; 1) shaping device; 2) operating chamber; 3) main source; 4) comparison chamber; 5) auxiliary source; 6) load resistance for the chambers; 7) micrometer screw for positioning the auxiliary source; 8) electrometer amplifier; 9) recorder.

In the dairy industry experiments have been carried out on the continuous control of the quality of dairy products by absorption of β - and γ -radiation [31]. Using the relation between the concentration of dry materials in condensed milk and the density of this product a method has been developed for automatic control of the quality of condensed milk in which a radiation densitometer (PZhr-1)* is used.

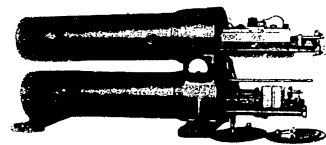


Fig. 8. External view of the data-pickup device used in the automatic control of the weight of a moving fabric.

*PZhr-1 is a radiation densitometer for liquids [32] for general industrial use (a refinement of The Scientific Research Institute for Thermal Instruments, MPSA).

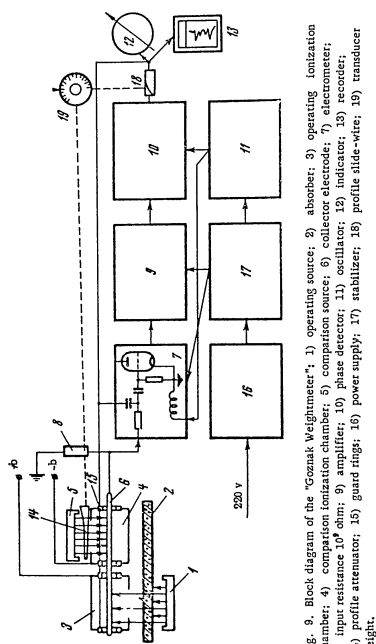


Fig. 9. Block diagram of the "Goznak Weighometer": 1) operating source; 2) absorber; 3) operating ionization chamber; 4) comparison ionization chamber; 5) comparison source; 6) collector electrode; 7) electrometer; 8) input resistance 10^8 ohm; 9) amplifier; 10) phase detector; 11) oscillator; 12) indicator; 13) recorder; 14) profile attenuator; 15) guard rings; 16) power supply; 17) stabilizer; 18) profile slide-wire; 19) transducer weight.

In the manufacture of refractory materials, A. N. Lyulichev and E. V. Levintovich have carried out work on a non-contact determination of the weight by volume of refractory objects in the region from $0.75-3.35 \text{ g/cm}^3$ and have obtained data for the construction and design of special apparatus for automatic control of the quality of refractory material.

In the gas industry and in communications it is extremely important to develop above-ground methods for locating damage points in underground trunk lines. Work in this field has been directed primarily toward determining leakage points in gas lines [33] and breaks in the hermetic lead shield around communication cables [34].

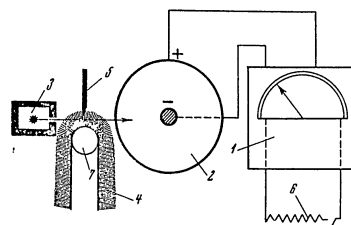


Fig. 10. Diagram of the apparatus for measuring fur thickness with a radiation thickness meter: 1) vacuum-tube amplifier with galvanometer; 2) ionization chamber; 3) radioactive radiator; 4) fur pelt; 5) straight edge boundary; 6) shunt; 7) roller.

In both cases the damaged trunk line is filled with radioactive gas (methyl bromide or radon) and the leak is located from the surface using an ordinary field-type radiometer.

In the plastics industry, in rolling large quantities of plastics, automatic stops are used for the rollers [35]. The working principle is as follows: on the operating arm of the device are placed collars containing sources of insignificant and completely harmless doses of radioactive material. Radiation pick-up devices are placed in the danger zone and these control the stop. When the operating arm moves into the danger zone the roller is brought to a stop instantly.

In marine transportation, earth-removal machinery equipped with γ -depth meters is widely used in measuring river channels and other work. Systems furnished with γ -depth meters allow the dredging operation to be carried out by continuous remote control of the bottom content in the removed material, allowing optimum use to be made of the dredging machinery. During the useful navigation period in 1956 when the earth-removal equipment of the Ministry of River Fleet had 36 γ -depth meters in operation, according to S. N. Dedyukov [36], a saving of more than two million rubles per year was realized.

The Physics Institute, Academy of Sciences Latvian SSR [37] has developed a whole new series of relay-type instruments for a wide variety of industrial purposes. These instruments are used for object counting, for control of the level of beer in the brewing industry, for counting carcasses which are transported in the meat industry, for control of the filling of aluminum tubes with cream in the cosmetic industry, for regulating voltage and temperature in accordance with the position of the arrow of an indicating device with a radioactive source placed on it, and for many other purposes. An outstanding feature of all these devices is the use of a standard circuit, their small size and simplicity of operation. As an illustration, in Fig. 12 is shown an external view of a radioactivity-level meter (RIU-3) which is designed to measure the level of liquids in large-diameter vessels and in large carrying containers. The device contains only one vacuum tube and is very small. Using one of these instruments it is possible to measure the levels in many containers very rapidly.

The Scientific Research Institute for Thermal Instruments, MPSS, in recent years has developed and established in industry a whole series of devices for general industrial use (densitometers, concentration meters, level meters, consumption meters and so forth).

The possible use of a noncontact measurement of the density of a liquid [38] based on the absorption of γ -radiation in the liquid is shown in Fig. 13. In addition to the PZhR-1 densitometer mentioned above, the Scientific Research Institute for Thermal Instruments has developed more refined models, the PZhR-2 and PZhR-3. The PZhR-2 instrument uses a modulated radiation and a scintillation counter. In the PZhR-3 instrument use is made of a compensation scheme with a differential ionization chamber. An external view of the PZhR-2 instrument is shown in Fig. 14.

The radiation concentration meter, RKM-1 [39] uses the effect of back-scattering of β -radiation in the controlled medium (solution). The current produced in an ionization chamber by the β -particles reflected from a medium of complex chemical composition is approximately equal to

$$I \approx \sum_{k=1}^n (Z_k) c_k, \quad (2)$$

where $I(Z_1) \dots I(Z_n)$ are the currents due to reflection by the various components of the mixture; $c_1 \dots c_n$ are the concentrations by weight of the components.

For a binary mixture ($n = 2$) the sensitivity is given by the expression

$$S = \frac{dI}{dc} = I(Z_1) - I(Z_2). \quad (3)$$

The sensitivity becomes larger as the difference $I(Z_1) - I(Z_2)$ becomes larger, that is, the greater the difference in atomic number of the components of the mixture. An external view of a RKM-1 concentration meter is shown in Fig. 15.

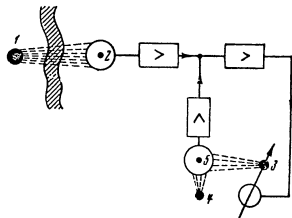


Fig. 11. Block diagram of the device for measuring the thickness of hides: 1) main radiation source; 2) main detector; 3) comparison radiation source; 4) auxiliary radiation source (for shifting the zero reading); 5) comparison detector.

The level meters developed by Scientific Research Institute for Thermal Instruments are presently being produced in industrial quantities.



Fig. 12. External view of the radioactivity level meter RIU-3.

Because of space limitations in the present report we cannot present a comprehensive review of all the devices which make use of absorption and scattering of nuclear radiation which are applied in the various fields of industry. However, even from the short description which has been given it is apparent that the field in which work is being carried out is large and that very important results have been achieved. For this same reason we are not in a position to give a comprehensive picture of the overall economic effect due to the introduction of these devices in industry.

All the instruments considered above should also be evaluated from the point of view of accuracy (noting, incidentally, other features of their operation). From this point of view it is convenient to divide all devices in which absorption is used into two basic groups:

a) Devices and methods of measurement the accuracy of which depends directly on the accuracy of measurement of the radiation flux. At the present time this group has been most widely developed;

b) Devices and methods in which the results of measurements are almost independent of the accuracy of the measurement of a radioactive flux and changes in the intensity of this flux or the conditions under which it is detected in the medium being controlled. In this group we include relay schemes and certain other devices which employ measurements of frequency, phase, or time.

a) Devices, the Accuracy of Which Depends on the Accuracy of the Measurement of a Radiation Flux

An analysis of the errors in the measurement of density or weight by absorption of radiation carried out on the basis of Equation (1) indicates that, in general, these errors are independent of the actual method and apparatus.

The uncertainty in the measurement of the average intensity of the radiation flux arises as a result of two independent factors [3], which are due to imperfections in the measurement apparatus and the statistical nature of radioactive decay:

$$\Delta J = \pm \sqrt{(\Delta J_{app})^2 + (\Delta J_1)^2} \epsilon, \quad (4)$$

where ΔJ is the mean square error in the measurement of the intensity of the radiation flux; ΔJ_{app} is the error due to imperfections in the measurement apparatus; ΔJ_1 is the error due to the statistical nature of decay.

The quantity ΔJ_1 can always be made rather small by choosing a source of high activity.

The minimum in ΔJ_1 occurs when

$$\mu_m \cdot \rho \cdot d = 2. \quad (5)$$

Hence, the choice of an isotope is determined by the best approximation satisfying the conditions given in Equation (5) in a given region.

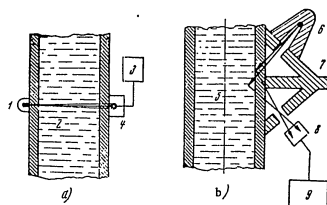


Fig. 13. Schematic diagrams of the non-contact liquid-density measurement: a) using γ -radiation absorption: 1) radiation source; 2) medium being controlled; 3) measurement device; 4) radiation detector; b) using γ -radiation scattering: 5) medium being controlled; 6) radiation source; 7) shield; 8) radiation detector; 9) meter.

Using Equation (1) and Equation (4) it is easy to determine the error in the measurements in any practical case.

For example, in a case where thickness is measured, differentiating Equation (1) we obtain an expression for the absolute error in the thickness measurement

$$\Delta d = \frac{\Delta J}{J_1 J} = \frac{\sqrt{(\Delta J_{app})^2 + (\Delta J_1)^2}}{\mu_m J_0 e^{-\mu_m d}}. \quad (6)$$

For a given requirement on the accuracy of the thickness measurement, the activity of the radiator is found from the expression

$$a = \frac{1.08 \times 10^{11} d^2}{\Delta d^2 J_1^2 \sqrt{\pi} \epsilon \Omega} \left(\frac{1}{2 \Delta d J_1 \sqrt{\pi} \epsilon} + \sqrt{\frac{1}{4(\Delta d)^2 \mu_m^2 \pi \epsilon} + (\Delta J_{app})^2} \right) \quad (7)$$

where τ is the duration of the measurement; ϵ is the detection efficiency; g is the number of quanta per decay event; and Ω is the solid angle subtended by the detector at the source.

ΔJ_{app} is independent of the activity of the radiator in the general case and can be reduced only by proper design of the measurement circuit itself.

The most ideal measurement circuits are those in which a compensation principle is used. In these circuits a comparison is made between two radiation fluxes, the one being measured and a comparison (or standard) flux; thus, the difference can approach zero in a continuous fashion. The application of the compensation idea allows one to reduce, to considerable degree, errors connected with changes in the external conditions and power supplies, variations in radioactive decay, etc. In Fig. 16 is shown a comparison circuit for measuring the thickness of rolled steel stock [40]. In this circuit a differential ionization chamber is used and errors which may be produced because of changing operating conditions in both halves of the chamber are relatively small.

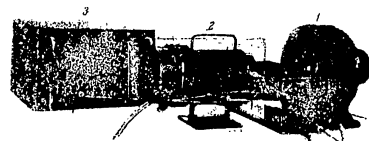


Fig. 14. External view of the PZhr-2 densitometer: 1) source unit; 2) detection unit; 3) electronics unit.

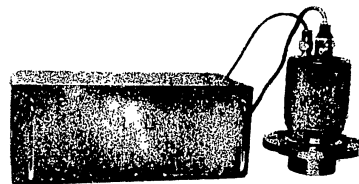


Fig. 15. External view of the concentration RKM-1 meter.

At the present time the scintillation counter is starting to receive more widespread acceptance; in the majority of cases, these devices are found to be much more effective than other radiation detectors (ionization chambers, Geiger-Muller counters) and require a radiator with a much smaller activity. However, because of its inherent instability the use of scintillation in comparison circuits in recent years has been attended by a number of difficulties. Although uncertainties due to varying operating conditions in both halves of a differential

ionization chamber can be neglected in the majority of cases, non-uniform changes in the characteristics of two scintillation counters practically exclude the possibility of using these in comparison circuits. This situation is an indication of the importance of the problem of developing comparison circuits which operate with one radiation detector. This problem has been solved successfully. Two approaches have been investigated [41]. In the first case, the flux being measured and the comparison (standard) flux are allowed to strike the same phosphor of the scintillation counter; each flux is alternately cutoff by a lead shield. From the phase of the fluctuations at the output of the photomultiplier it is possible to determine the sign of the unbalance and to compensate for it. Thus, in this scheme both signals pass completely through the same detection channel. One shortcoming of this design is the need for a heavy lead shield. In the second case, (Fig. 17), the flux being measured F_1 and the comparison flux F_2 strike different phosphors Ph_1 and Ph_2 which are connected by a light pipe C to the same photomultiplier. The light fluxes from the phosphors are interrupted by the opaque half-disc A and strike alternately the cathode of the multiplier. A shortcoming of this scheme is the need for two inputs (phosphors) which can exhibit different variations in their characteristics, as a function of time. However, in this scheme the chief cause of instability, i. e., the photomultiplier, can be excluded from consideration.

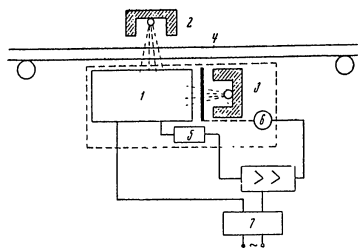


Fig. 16. Diagram of device for measuring the thickness of rolled-steel stock: 1) differential ionization chamber; 2) main radiator; 3) comparison radiator; 4) adjustable attenuator; 5) vibrator power supply; 6) servo motor; 7) rectifier.

Another step forward is represented by a scheme with a vibrating radiator [14] which is free from the shortcomings of the schemes mentioned above. This scheme was developed primarily for the control of density (Fig. 19) and comprises two radiation sources (the main source and the comparison source), one measurement channel and a comparison wedge. A feature of this scheme is the use of modulation; this is realized by means of two electromagnetic vibrators which operate in opposite phase. The radioactive radiators are placed at the ends of the vibrators. Changes in the phase of the unbalance signal control the position of the comparison wedge. No heavy moving parts are involved.

Finally, we come to one extremely interesting method [38]. This is the scheme used in the PZhR-2 densitometer (Fig. 19). The chief feature of this device is the fact that here, for the first time, has been successfully realized a comparison measurement scheme in which only one source and one radiation detector are used, that is, this scheme has the smallest possibility for apparatus errors. A feature of the measurement is the fact that the radioactive isotope is located on a rotating disc and alternately sends the radiation to the same scintillation counter through two paths; first, through the medium being controlled and then through the comparison wedge. The amplified unbalance signal controls the position of the comparison wedge.

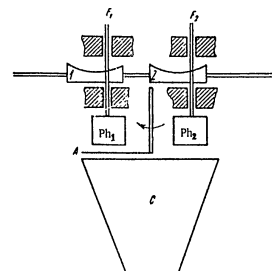


Fig. 17. Scheme for measurement with two phosphors: 1) object being controlled; 2) standard.

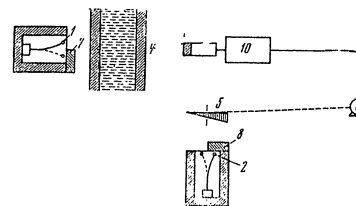


Fig. 18. Diagram of the densitometer with vibrating radiators: 1) main radiation source; 2) comparison (standard) source; 3) phosphor; 4) light pipe; 5) comparison wedge; 6) reversing motor; 7) and 8) lead radiation diaphragms; 9) photomultiplier; 10) amplifier.

From a consideration of the cases which have been presented, it is apparent that a number of potentialities in automatic control techniques have been opened by the use of modulated nuclear radiation.

b) Devices, the Accuracy of Which is Independent of the Magnitude of the Radiation Flux

As has been indicated in our survey above, relay-type operation has found wide application in a number of different fields of industry. A distinguishing feature of relay schemes is their simplicity and the fact that the magnitude of the radiation flux (once the threshold has been exceeded) does not affect the results of the measurements. A typical scheme, that developed by the Institute of Physics, Academy of Sciences, Latvian SSR (Fig. 20)

operates on alternating current and has been used widely, in particular, for position-regulation of voltage [37]. A thyatron relay of the All-Union Central Scientific Research Institute for Ferrous Metals (Fig. 21) is used mainly for control of the level of liquid metals.

Of particular interest is the circuit of a γ -relay in which transistors are used (Fig. 22) and one in which a scintillation counter is used (Fig. 23); these have been developed at the All-Union Coal Scientific Research Institute for automation in the coal-mining industry. The possibilities for use of radiation relays are extremely wide. For example, in addition to the excellent but complicated densitometer which makes use of modulated nuclear radiation, attention is merited by the extremely simple position density regulator developed at the Institute of Physics, Academy of Sciences, Latvian SSR [37]. This regulator (Fig. 24), which consists of an ordinary hydrometer which does not make contact with anything and is very accurately controlled by the radiation relay, makes it possible to realize continuous control and regulation of the density of a liquid. This circuit contains only one vacuum tube and the use of relay-type operation means that changes in the radiation flux have no effect on the results.

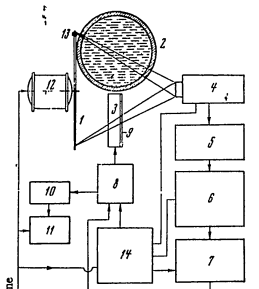


Fig. 19. Diagram of the PZhr-2: 1) disc; 2) object being measured; 3) comparison wedge; 4) scintillation counter; 5) integrating unit; 6) amplifier; 7) phase-sensitive device; 8) reversing motor; 9) needle; 10) induction coil; 11) auxiliary device; 12) synchronous motor; 13) radioactive source; 14) power supply.

A natural transition from position control using a relay scheme to continuous control is the apparatus developed by the Institute of Physics, Latvian SSR for counting products which pass along a conveyor.

On one side of the conveyor there is a radiation source, on the other there is a detector which sends a pulse to the counting circuit each time the radiation beam is interrupted by an object on the conveyor. The counting accuracy is independent of the accuracy of the measurement of the radiation flux and the position of the object on the conveyor.

To demonstrate the possibilities of development along these lines we consider in greater detail a frequency liquid rate of flow meter developed at the Institute of Automation and Remote Control, Acad. Sci. USSR [42].

A general idea of the apparatus is shown in Fig. 25. The flow of liquid causes the rotation of an impeller wheel on one of the vanes of which is placed a small amount of radioactive material 1. The radiation flux

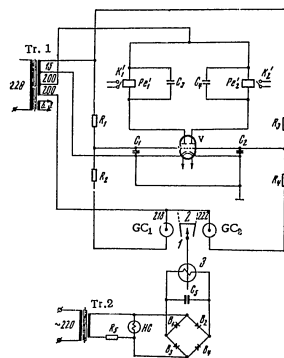


Fig. 20. Typical relay scheme developed by the Institute of Physics, Academy of Sciences, Latvian SSR: 1) radioactive isotope; 2) shield; 3) measuring meter.

penetrates the wall of the pipe line and strikes a radiation detector 2 connected to the indicator 3. In the path of the radiation flux is located a shield 4 which is chosen so that the radiation strikes the detector only for a short interval of time in each revolution of the impeller wheel. Hence, the number of radiation pulses which strikes the detector is equal to the number of revolutions of the impeller. At the output of the indicator unit there is a meter 5 which reads the value of the instantaneous rate of flow and an electromagnetic pulse register 6 which records the integrated consumption.

The thickness l' of the shield is chosen from the formula

$$l' = \frac{\ln m}{\mu_1}, \quad (8)$$

where m is the required depth-of-modulation of the radiation; μ_1 is the linear absorption coefficient for γ -radiation of the given isotope in the shielding material.

The accuracy of the measurement in any given case is independent of the accuracy of the measurement of the radiation flux and is determined by the quality of the measurement circuit and can be made quite high if so desired.

As a matter of fact, this method of measuring rate of flow and consumption is actually based on the notion of a non-contact tachometer; hence, all that has been indicated applies in other cases in which it is desired to measure the rotational velocity of inaccessible objects.

We may note that the use of a differential relay scheme allows one, in a number of cases, to increase the accuracy of a measurement by almost an order of magnitude.

The analysis which has been carried out gives an indication of the importance of careful consideration of the approach to these problems and indicates the potential development of methods in which modulated-radiation and flux-independent techniques are employed.

2. Use of Radiation-Induced Ionization in the Material Being Controlled

The ionizing properties of nuclear radiation have been used widely to control the technical parameters of gaseous media. The current of an ionization chamber inside of which an α -radiation source is located is proportional to the pressure P in the chamber (neglecting recombination) and is equal to

$$I = 3.7 \cdot 10^7 a \eta e \frac{P}{760}. \quad (9)$$

Here a is the activity of the source in millicuries; η is the utilization factor for the source; e is the charge of the electron; η is the number of ion pairs produced by an α -particle in 1 cm of path; l is the dimension of the chamber; P is the pressure of the gas in mm Hg.

This effect has been used [43] in the development of devices for controlling gas pressure.

If the pressure in the ionization chamber is maintained at a constant value, I will depend on the composition of the gas medium; from this fact there follows the possibility of realizing automatic control of the composition of a gas. The first steps in this direction were taken by N. I. Shteinbok [44] and showed that this important and necessary work merits a great deal of attention.

If the gas flows through the ionization chamber, some of the ions are carried from the chamber, and the current I is reduced. A scheme based on this principle, which is used to measure the velocity or consumption of a gas [45], is shown in Fig. 26. Two electrodes, at different potentials, are placed in the path of a gas flow. A layer of radioactive material is placed on one of the electrodes, thereby ionizing the space between the electrodes. The ions which are produced under these conditions move with a velocity which is determined by two factors.

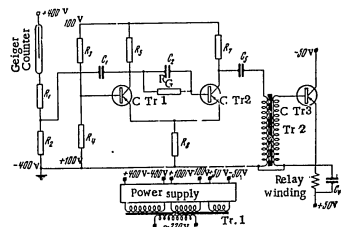


Fig. 22. Diagram of the γ -relay from All-Union Central Scientific Institute for Ferrous Metals.

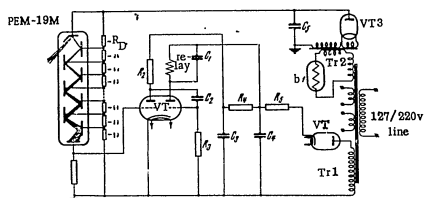


Fig. 23. Diagram of a fast-acting γ -relay from All-Union Coal Scientific Research Institute.

1) A component along the y axis representing the velocity of the ion motion along the lines of force of the electric field

$$V_y = kE, \quad (10)$$

where k is the mobility of the ions; E is the intensity of the electric field;

2) A component along the x axis, representing the velocity of the gas flow V_x .

The larger the value of V_x the larger the number of ions that are removed from the interelectrode space and the smaller the current in the circuit.

We should point out that the ionization current depends on other things besides the rate of flow, in particular, the radiation intensity, the mobility of the ions, and recombination.

Some increase in accuracy can be achieved by the application of a differential circuit connection [32]; however, the effects due to changes in mobility and ion recombination remain.

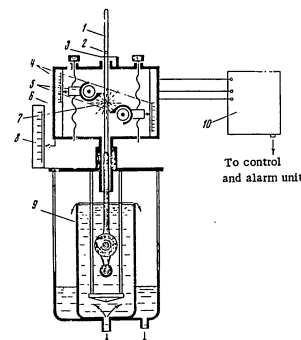


Fig. 24. Diagram of a non-contact density regulator developed by the Institute of Physics, Academy of Sciences, Latvian SSR: 1) hydrometer; 2) visual indicator; 3) pointer; 4) scale for setting the counters (determining the limits of the density being regulated); 5) gas counter; 6) container; 7) radioactive isotope ^{90}Sr ; 8) density scale; 9) measurement beaker; 10) control and alarm unit.

$$a = \frac{n_{\text{pair}} \delta E}{3.7 \cdot 10^9 \tau_{\text{rad}} \eta_{\text{rad}} (1 - \tau_{\text{back}} \Delta E_{\text{mean}})}, \quad (11)$$

where δE is the energy required for the production of one ion pair in the gas being considered; τ_{rad} is the irradiation time; η_{sp} is the spectral utilization factor; η_{rad} is the utilization factor for the radiation, which indicates what part of the total number of particles produced in the decay of the β -particle

are particles which move in the direction of the radiation beam in the side of the tube; τ_{back} is the coefficient for back-scattering of the β -radiation; ΔE_{mean} is the mean loss of energy of particles in the packet; n_{pair} is the required number of ion pairs in a packet determined by the formula

$$n_{\text{pair}} = \frac{I_{\text{cs}} D^2}{k_c U_{\text{det}}}, \quad (12)$$

where I_{cs} is the current sensitivity of the detector; k_c is a constant; U_{det} is the voltage between the plates of the detector; D is the diameter of the pipe.

The following features are characteristic of this method of gas-consumption control: a) the absence of any contact between the measuring elements and the gas, b) the absence of any dependence of the measured

results on changes in the magnitude of the radiation flux and properties of the gas flow (the measurements are of an absolute nature and the accuracy is determined only by the accuracy with which the time and the distance are measured).

At the present time the Scientific Research Institute for Thermal Instruments, MPSSA has developed samples of an industrial consumption meter RGR-1 for general industrial use, which operates by this principle [48]. In the consumption meter a successful application has been made of a comparison measuring circuit in which the drift time is kept constant and the distance between the radiator and the detector is changed as the consumption changes. The use of a comparison scheme allows a considerable improvement in the accuracy of control. An external view of the consumption meter is shown in Fig. 28. According to the data, this rate-of-flow meter is a considerable improvement over those which have been developed abroad [49, 50] in which consumption is measured indirectly by the removal or recombination of ions.

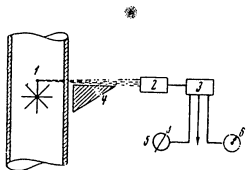


Fig. 25. Diagram for the liquid-rate-of-flow meter of the Institute of Automation and Remote Control.

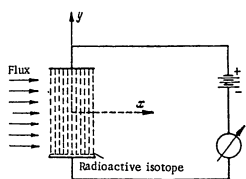


Fig. 26. Control of gas consumption or velocity by ion removal.

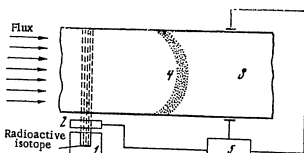


Fig. 27. Automatic control of gas consumption by a tracer-molecule method; 1) nuclear radiator; 2) modulator; 3) detector; 4) ion packet; 5) time-measuring device.

3. Use of Nuclear Spectroscopy Methods

We have mentioned above that this approach in the technique of automatic control has as yet, just been touched upon. All existing methods of automatic control, as a rule, make use of the integrated effect of radiation flux without separating the individual components according to energy. However, because of the fact that each of these components interacts differently with the material being studied, the possibility arises that this feature can be used to obtain additional information about the composition of the material. The development of simple radiation detectors, sensitive to only a given portion of the energy spectrum, and the concomitant development of computer techniques for automatic analysis of the data of combined measurements furnishes the

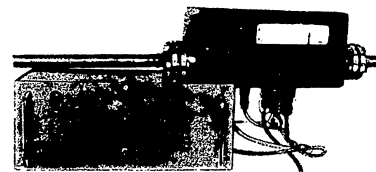


Fig. 28. External view of the RGR-1 rate-of-flow meter.

possibility of building machines for non-contact automatic control of the composition of multi-component mixtures.

The energy of the reflected γ -radiation is affected strongly by the energy of the γ -radiation emitted by the source. Owing to this situation it is possible to measure selectively the radiation intensity, using γ -spectroscopy methods. The wide application of these devices depends chiefly on the development in a form suitable for industrial application of γ -spectroscopy techniques, primarily scintillation methods.

By using a group of radiation sources with different energies, one can determine simultaneously the concentration of the individual components in a multi-component system. The development of automatic machines of this type also requires the development of appropriate computer techniques.

A significant step forward in the use of the spectral properties of radiation would be the use of secondary radiation (bremsstrahlung and x-rays), produced in the interaction of β -particles with matter. By changing the disposition and material of the target, one can form regulated sources of secondary radiation at a given energy or, conversely, can determine the composition of a target by changes in the secondary-radiation spectrum.

A practical step in the use of spectroscopy methods for automatic control is represented by the development of a device for automatic "one-side" control of the thickness of objects at the Institute of Physics, Academy of Sciences, Latvian SSR. This device operates by virtue of the fact that the thickness of an object can be gauged from the intensity of the back-scattering of γ -radiation from Cs^{137} , the energy spectrum of which is entirely different from the primary radiation. Using a scintillation detector and special discrimination it is possible to distinguish the secondary radiation spectrum. There is no need for unwieldy lead shielding. The apparatus is comparatively simple and convenient for measuring thickness of objects of which only one side is available for measurement.

There is no doubt that the application of radiation-spectroscopy methods in measurement and control will receive extremely intensive development in the hands of both physicists and people concerned with measurement techniques.

4. Use of Neutron Flux

In turning to methods based on the use of neutron fluxes we should make mention of the potentialities and the relatively small amount of work which has been carried out in this field. In technological process control use can be made of the absorption, scattering, and slowing-down of neutrons in the medium being controlled. Neutrons can be used in measurements of the moisture contained in different materials, in defectoscopy of thick objects, in "one-side" control of the level of hydrogenous materials, in control of temperature, and various other applications.

There are several extremely interesting methods for automatic control of the composition of materials in which use is made of neutron fluxes [51]. Nuclear reactions are used for activation analysis; these reactions lead to the production, in the material being exposed to the neutron flux, of various radioactive isotopes.

From the intensity, form, and energy of the radiation due to the induced radioactivity, it is possible to get information on the composition of the material. The higher the induced radioactivity, the greater the accuracy with which the element content can be determined. This technique is not very useful for automatic control of continuous technological processes since the magnitude of the radioactivity required for stable detection is such as to require extremely intense neutron fluxes; also, the product being examined becomes highly radioactive. Phenomena more suitable for continuous technological control are nuclear reactions of the type such as (n, γ) which frequently are not accompanied by the production of radioactive isotopes and require considerably smaller neutron fluxes, which can be easily obtained from low-intensity neutron sources of the $(Po + Be)$ type, etc. In this case, the radiation intensity J depends on the intensity of the neutron flux Φ , the effective cross section for capture in the appropriate nuclear reaction σ , and the number N of atoms of the element which undergo the reaction. Thus,

$$J = \Phi \sigma_a N. \quad (13)$$

It has been shown experimentally that whereas an accurate activation analysis of the contents of the majority of elements requires neutron fluxes of the order of 10^8 neut/cm²-sec and higher, the use of nuclear reactions usually means that fluxes of from 10^4 to 10^6 neut/cm²-sec are sufficient. In this case the secondary radiation can be detected continuously and analyzed in detection apparatus directly while the neutron irradiation of the material being controlled takes place. The successful solution of the problem of automatic control requires the construction of detection apparatus of high efficiency for secondary radiation and low sensitivity to the primary neutron flux, the development of simple spectrometers which are rapid in operation, and the development of computer techniques for evaluating the combined measurements.

Mention should also be made of the use of modulated neutron fluxes. Methods in which tracer atoms are used are not widely applied in automatic process control since they usually require the contact of radioactive isotopes into the material being controlled and the subsequent removal and dosimetry of the sample. The application of modulated neutron radiation opens the possibility for automation of this process. For example, to realize non-contact automatic control of the consumption of material passing along a tube, the tube can be irradiated by a continuous neutron flux at a certain point. An automatic measurement of the drift time of "hot" objects in the medium provides an automatic and non-contact determination of consumption. These problems require a great deal of work on the production and development of suitable methods for modulating neutron fluxes and measuring small activities but will undoubtedly be feasible in the future.

Improvement of process technology. Automation very frequently requires an appraisal of industrial technological processes from the point of view of increasing the speed, simplicity of control, and reliability of the apparatus.

Nuclear reactions can be used to intensify chemical processes, to improve the properties of certain scintillating materials and semiconductor, to remove static electric charges which are produced in industrial processes, and in many other cases.

For example, the removal of static charges is of considerable interest in a number of industrial fields (paper manufacture, textiles, defense, chemistry, movie films, etc.). We present an example from the textile industry. Winding of synthetic fibers is extremely difficult because the threads become electrified and tend to separate. This effect reduces sharply the speed of the winding machine and causes a deterioration in the quality of the product. The Institute for Automation and Remote Control, Academy of Sciences, USSR in conjunction with the Shcherbakov Silk-Weaving Combine and the All-Union Central Scientific Research Institute of Silk has carried out work on the removal of static charges at the weaving machines of the Shcherbakov Combine. The results of this work indicate [52] that the use of a radiator at the winding machine makes possible a three-fold increase in the production rate without deterioration of the quality of the product.

SUMMARY

1. The material presented in the present report gives an indication of the large scope with which work on the use of nuclear radiation is being carried on in the Soviet Union toward the control and automation of technological processing and on the potentialities which have been opened for the further development of this field.
2. New and original methods and devices in which nuclear radiation are applied have been developed for control of industrial processes in the USSR. In the majority of cases these devices and methods have been tested industrially and have been widely used for both selective and large-scale automatic control and have resulted in widespread savings in the national economy.
3. The following steps will be required to further the development in the fields which have been indicated and to extend the fields of application of industrial devices in which nuclear radiation is used:
 - a) it will be necessary to increase the scale of operations at the Academy of Sciences, USSR and the associated republics, and the scientific research institutes of the various fields of industry in theoretical research in the development of new instrument systems and, in particular, systems for general industrial use of automatic control of manufacturing processes. It will be necessary to improve the coordination of the work in this field;
 - b) it will be necessary to enlarge the specialized construction bureaus, plants, and works which manufacture measurement and control apparatus, new electronic and semiconductor devices and automatic measuring apparatus using nuclear radiation;
 - c) it will be necessary to improve the quality, and durability of, and to simplify the delivery of, radioactive radiators. It will also be necessary to make more precise the existing rules on work protection in divisions which are concerned with the use of radioactive radiation in industrial control instruments and devices;
 - d) it will be necessary to extend the education of specialists on the nuclear-radiation control of technological industrial processes at the institutions of higher learning and technical institutions.
4. Only solutions of all the complex problems which have been considered will make it possible to solve in a meaningful way the problem posed by the 20th Congress of the Communist Party of the Soviet Union on the use of nuclear radiation in automation and apparatus construction.

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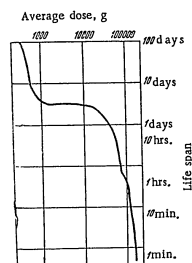
THE ORIGINS AND SYMPTOMS OF THE ACTIONS ON
LIVING ORGANISMS OF SMALL RADIATION DOSES

A. V. Lebedinsky

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Ionizing radiation has only been relatively recently considered in work on the effect of various external factors on organisms. Quite naturally, attention was initially paid to effects from large doses of ionizing radiation. With regard to its lethal action, the effect can be demonstrated graphically (See Figure).



Mean life span after single-shot whole-body X-ray irradiation (white mice)
(From Rajewsky *).

These experiments have revealed many sides of the problem concerning the actions of ionizing radiations on living organisms. A criterion of such action is the abrupt disturbance and termination of vital activities. Naturally, such an estimate is of no value at all in drawing conclusions as to the importance of change in the natural level of ionizing radiation on the life-span. A simple calculation shows that even when the work is carried out with small doses of limited usable magnitude the level is some 150 times that due to the constant action of natural radiation sources.

In this connection, the problem of the action of small doses of ionizing radiation on the human organism has assumed particular importance because the natural radiation level has been raised in recent years. This is mostly due to the testing of nuclear weapons, which tests have so far not merely ceased, but have even become more widespread in spite of the repeated declarations by the Soviet Government that they should cease. The relative data show that the rise in the natural radiation level is due both to a rise in the γ -ray background, and particularly to the increase in radiation sources present within the human body.

Four sources of natural radiation are known at the present time: cosmic rays and radiations from radioactive elements in the soil, in the air and in the tissues and fluids of animals and man.

Measurements show that the cosmic radiation, which originates at a great height, gives a dose equivalent to 0.028r/year to man at sea level. The main sources of radioactivity in the earth are uranium and thorium which decompose to daughter radioactive elements also emitting γ -rays and nuclear particles. Being present in the earth's crust and in the materials used for building purposes they also give a dose of about 0.028r/year. Certain data enable us to assume that the irradiation of the internal environment due to radioactive trace

* B. Rajewsky, *Strahlendosis und Strahlenwirkung* (G. Thieme Verlag, Stuttgart, 1956).

elements present in the tissues is some 70% of this figure, i.e., about 0.03 r/year.* The radioactive sources in the atmosphere are the gaseous decomposition products from uranium and thorium - radon, the concentration of this being some $0.3 \cdot 10^{-12}$ c/liter of air. On the average we may assume that this source (air) produces a radiation dose of about 0.001 r/year to man.

The radioactive elements present in the body are K^{40} , C^{14} , Cs^{137} , Ra and certain others. The potassium is about 0.2% by weight, being mostly present in muscle (up to 0.35%). The radioactive isotope K^{40} is about 1/8000 of this. The dose rate due to the isotope is about 25 mrad/year. Carbon is present in all organic compounds, comprising about 18.2% by weight of the human body. The C^{14} content is some 10^{-12} of the total carbon, thus giving a dose of about 1.5 mrad/year to man.

Thus, the general contribution due to radioactive carbon and potassium in the body is equivalent to a dose rate of about 27 mrad/year.

In addition, there is the skeletal radium, amounting to about $60 \cdot 10^{-12}$ gm in areas of normal radioactivity, i.e., where the radium content in the water is about 10^{-13} gm/liter. The radiation from the skeletal radium, according to the work of English investigators, gives a dose rate of about 37 mrad/year*** to the skeleton.

Since the radioactive elements are present in the body it is constantly subjected to the action of γ -rays and α - and β -particles. Sievert's recent work [1] has shown that the K^{40} is the main γ -ray source for man; the fraction due to radium is not more than 2%. The β -particle sources are K^{40} and C^{14} . α -particle irradiation is due to radium, thorium and radon.

This short description of the natural level of ionizing radiation which gives a dose rate to man of about 0.1 r/year from both internal and external sources does not allow for the radium present in osseous tissue.

The dose received may vary within certain limits. Variations are observed in the cosmic ray intensity in a given locality, but these are of short duration and do not usually exceed some tenths of a percent. In some areas of the earth, particularly where there are monazite sands, terrestrial radiation may be some 10 times greater than in areas of normal activity, and the dose rate may reach 0.6 r/year. The increased radium content may cause the activity of inspired air to reach 10^{-12} c/liter, depending on the weather conditions. Assuming the most unfavorable combination of factors we take it that the dose from external sources may vary up to 0.1 r/year, and in certain restricted areas of the Earth's surface up to 0.6 r/year.

With regard to the natural radiation level, this changes with the K^{40} content of the organism, which is mainly determined by the muscle developed. The γ -ray intensity variations found for bodies by Sievert are 20 - 30% of the mean. The data available on the radium contents of human bones from different localities show that this varies with the area: from 10^{-9} to $4 \cdot 10^{-8}$ gm and from $3.8 \cdot 10^{-11}$ gm to $4.3 \cdot 10^{-10}$ gm per skeleton. The possible rise in the content of this element requires particular attention.

Radium is a well-known deposit in bones; allowing for equilibrium between radium and its decay products, we may assume that the energy in the short-range α -particles is five times greater than that in the β - and γ -rays, i.e., as the radium content rises it is only the bones that receive the main increase in radiation dose. Allowing for this, we may conclude that the possibility of increased natural radiation is mainly due to the increase in the K^{40} content, i.e., not more than 0.012 r/year. Similarly we may assume that the radiation dose due to natural activity varies from 0.1 to 0.12 r/year, except for territories where terrestrial activity is high, and making no allowance for increased skeletal radium.

As was noted above, nuclear weapons tests have raised the natural background in recent years. Fine particles of radioactive fission products formed in the explosion are deposited from the air. They penetrate into the upper stratosphere and are blown about by the air currents found at this level, and 10-20% fall on the earth's surface annually. Since they depend on the direction of the air streams and the local relief, the amounts of

these deposits of radioactive fission products are very variable.

This radioactive fission-product fall-out causes a rise in the natural radiation level. The Sr^{90} and Cs^{137} are the materials most important to man in the fall-out.

Cs^{137} (33 years) raises the γ -activity of the earth's surface. Since Cs^{137} takes part in biological cycles, and is incorporated into organisms, it can increase the natural activity of the human body.

The rise in γ -background is not the same everywhere. Data published recently show that the surface radiation at various points in the USA rose during the period from October, 1952 to September, 1955 from 5.8 mrad (San Francisco) to 160 mrad (Salt Lake, Utah). The corresponding figure for New York was 17 mrad, and for Chicago 24 mrad [2].

For 1956 sufficiently detailed figures on the Sr^{90} activity deposited at various points on the Earth's surface from fall-out have been compiled.

The figures show that in various areas of the USA the Sr^{90} fall-out varied from $1.62 \cdot 10^{-3}$ c/km² (New York) to 8.85 c/km² (Salt Lake). We are currently attempting to compute the rise in activity that has since occurred from Sr^{90} fall-out. Supposing that tests of nuclear weapons were to cease at once, we would expect that the activity would rise until 1968, equilibrium then being reached. A high level of $14 \cdot 10^{-12}$ c/km² will occur in places which today have the lowest Sr^{90} content. The English calculation which is based on the assumption that the tests will continue at the same rate as at present indicates that in 100 years time levels of the order of 200×10^{-3} c/km² will be reached [3].

Thus, we must expect a rise in the natural background due to increased earth γ -activity and natural radioactivity of the human body. The latter is due to Sr^{90} which mostly causes increased activity in the osseous tissues in which it is deposited. But the body γ -activity can also rise due to deposition of Cs^{137} which is a natural component of the radioactivity in the human body, as recent investigations have shown.

The absolute magnitude of the rise in natural background is at present small, the rise in earth γ -ray background being about 0.1% of the natural level. It is otherwise with the increase of body irradiation due to the Sr^{90} fall-out.

This isotope occupies a special position for a number of reasons, primarily because it participates in biological processes.

Sr^{90} plays a particularly important part in biological processes. It enters the human body inevitably even when uptake from dust and water is prevented.

The biological chain begins with the incorporation of Sr^{90} into plants. Since it is deposited on the top layers of soil, it enters the plants together with the calcium, particularly with agricultural crops. According to Klechkovsky's data [4], when the rate of uptake in the above ground parts of the plants (wheat) are compared for various radioactive isotopes (of zirconium, strontium, cesium and ruthenium), it is found that the strontium is taken up most rapidly. The uptake of Sr^{90} in the plant may be considered as a specific process of biological concentration of this element. According to B. V. Kurchatov, P. M. Chulikova and V. P. Shvedova [5] the soil contamination per km² is about 5 mc in some areas of the USSR. The activity per km² was about 0.1 mc in dry grass, i.e., some 20% of the Sr^{90} is taken up in a comparatively small amount of hay.

The uptake in plants is the first step in the chain which ends with deposition in human bones and the irradiation of organs enclosed in the bony tissue.

We now turn our attention to the initial link in this process. This process is such that at equal degrees of contamination the Sr^{90} uptake varies on different soils. Klechkovsky's data show that beans accumulate this isotope to a greater extent than do cereals. Hence at the same degree of soil contamination and with the same soil, the population will be variously affected by the contamination according to the crop type which is dominant.

The next link in the biological chain is Sr^{90} incorporation into animals, particularly into cow's milk. Yu. I. Moskalov and D. I. Ilyin have studied the process recently [6] and have found that when the Sr^{90} solution is injected into the cow in a single shot, the concentration is 0.03% of the amount on the third day. The total Sr^{90} output on the fifth day is about 0.04% of the amount injected.

* As in Russian.

** A rad is the unit of absorbed dose for all forms of ionizing radiation, equal to 100 erg/gm; millirad (mrad) = 0.001 rad.

*** A reb = roentgen equivalent biological. It is the amount of energy absorbed by a tissue which is biologically equivalent to 1 r of X or γ -rays; millireb (mreb) = 0.001 reb.

We must emphasize that single injections of strontium were used in these experiments. When we may assume a systematic uptake from fodder containing this radioactive isotope the relationships will be different. The reason is that not only the strontium present in the food, but also the strontium loosely bound to various tissues (particularly that bound to bony tissues), will appear in the milk. According to Moskatov and Ilyin's data the latter process has a biological half life of about 350 days. Hence, even if the cow eats contaminated fodder for only a short while, the Sr^{90} will be eliminated in the milk for a long while. Some 1.5% of the injected Sr^{90} is taken up in the bones. Thus the second link in the chain - the animal - introduces a new feature into the fate of the Sr^{90} - its prolonged fixation in the site of uptake, due to its participation in the metabolism of bone salt.

Measurements of milk and bone activities show that their contents of this isotope have increased continuously during recent years, reaching 5.3 strontium units in New York, i.e., 3.3×10^{-12} c/gm Ca.

It would be of exceptional importance to analyze data on the Sr^{90} contents of human bones which would reveal the end of the biological chain. Unfortunately only single measurements have been made. But even these show that Sr^{90} is present in bones to the extent of about $2 \cdot 10^{-12}$ c/gm Ca. So we may assert that not only is there a tendency for the natural radioactivity to increase on account of the Sr^{90} fall-out at the present time but also that the activity of the human body is rising since the isotope takes part in the biological chain.

When evaluating the importance of Sr^{90} fall-out to man we cannot afford to neglect yet another chain in which it participates, which is of particular importance to populations consuming sea foods - fish, molluscs and seaweeds. In these objects increased biological concentration of the radioactive isotopes is seen particularly clearly. According to Marei's data [7], when uranium fission products or $\text{Sr}^{90} + \text{Y}^{90}$ are added to aquarium water the specific activities of fish bones are 657 and 563 times greater than those of the water, respectively; for the fish muscle the figures are 24 and 13 times; for the bodies of molluscs (toothless) they are 420 and 133; in algae the ratios are 810 and 280. For crab muscle the ratio is 350 when a fission-product solution is used. For plankton (*Daphnia*) in water containing $\text{Sr}^{90} + \text{Y}^{90}$ the figure is 10^{-4} (when the specific activity of the aquarium water was 10^{-10} c/liter).

We cannot neglect Cs^{137} when describing the rise in the inherent radioactivity of living organisms, since this also takes part in biological cycles, although in a rather different way from Sr^{90} . The important basic difference, emphasized by Klechkovsky, is that Cs^{137} is, to a considerable extent, bound in a non-exchangeable form by the soil and so enters into plants in amounts much less than in the case of Sr^{90} . But Cs^{137} appears in cow's milk in amounts some five times greater than Sr^{90} (relative to that injected). In addition it enters the human body by an additional route, i.e., via animal flesh; some 5% of the injected Cs^{137} appears in the ruminant's flesh.

The fact that the biological chain ends with man is of considerable importance to the fate of fall-out. When the radioactive isotopes (particularly Sr^{90}) enter the human body via milk or flesh, they are incorporated as indicated above. An important physiological factor accelerates this process. Animals with single stomachs, including man, absorb more radioactive isotopes from the gastrointestinal tract than do the ruminants, so the deposition is more complete. The difference is by a factor of 5 for Sr^{90} and Cs^{137} .

The increase in body activity which is at present occurring has received continued attention primarily because of advances in the medical sciences. We have in mind particularly the vast increase in the use of x-rays which are essential in the diagnosis and treatment of some diseases. According to the English data, the dose received by humans in this manner now amounts to about 22% of the natural level.

All this undoubtedly implies a change in the conditions in the environment in which man lives. The question arising which demands an answer is: what consequences may this have for humanity?

Very great difficulties are encountered in giving an answer to this question at the present time. This is due to our lack of knowledge as to the role played by radiation energy in normal life processes.

All we can say in answer to this question is to state the following facts: 1) organisms are capable of concentrating radioactive isotopes; 2) the isotopes are nonuniformly distributed amongst the various systems in the organisms.

It is presumed that the natural activity has a certain importance in causing variability in genetic materials. It is considered that 1/1000th of the natural mutations found in the fruit fly are caused by natural

importance to the performance of vital activities. On the other hand, there are a number of pieces of information which oblige us to exercise caution concerning deductions based on the undoubted existence of "specific" relations of the organism to ionizing radiation taken as a factor in the environment.

The criterion to which we refer consists in estimating the degree to which the destroyed functions are restored, i.e., the reversibility of the changes caused by the ionizing radiation. From this point of view all of the changes we have indicated are "unessential" regarding performance of vital activities: i.e., the changes in the numbers of mature cells in the blood, anomalies in some cells, reduction in the number of spermatozooids, depression of epithelial mitotic activity, changes in the EEG's at these doses - all of these are only temporary disturbances, i.e., they are completely reversible.

From this point of view, all the initial changes present no obstacle to the performance of vital activities. By evaluating the initial changes via their reversibilities we might hope, as it were, to obtain some sort of answer to the question. But this is not so, and a number of serious difficulties arise when we attempt to use this criterion to evaluate a number of other changes produced by ionizing radiation.

The first difficulty is encountered when this criterion is applied to changes occasioned by radioactive materials incorporated in the body. Any type of recovery naturally implies the removal of the causal agent, or else the production of a physiological state in the living substrate which goes by the name of 'adaption'. When the natural body background is raised by isotopes of long half-life this condition is not maintained; on the contrary a particular type of integrated change occurs. Thus, the 'restoration' criterion is inapplicable or has a very restricted application when evaluating changes produced by materials incorporated in the body. Thus, we first have to deal with the effects due to integration of changes. This integration is not only due to the prolonged action of the material but also to the summation of effects due to internal and external irradiation; one of the principal biological features of the actions due to various types of ionizing radiation is that the primary effects are nonspecific; this, of course, facilitates summation.

The second difficulty is due to the existence of changes to which there is no physiological compensating action. This refers to changes in genetic materials which have genetic consequences, and also to disturbances produced during development. Actions which are expressed via a temporary depression of the rate of development of some definite cells of a growing organ may be nonreversible since during the depressed period other undamaged cells may continue to develop and become adult. The initial changes are irreversible in such cases.

V.V. Yakovlev's experiments may serve to illustrate this; he found that irradiation of pregnant rabbits on the 9th day after fertilization, i.e., at the time when the organs of the central nervous system are beginning to form, caused a marked disturbance in the reflex activity of the foetus on the 20th day. Ionizing radiation is well known to cause teratological anomalies if it acts on embryos while the organs are forming.

Finally the third difficulty in using the reversibility criterion is as follows. As is well known, changes due to ionizing radiation occur, which are in essence injuries to tissues in which the depolymerization of protein complexes is a basic process [22], lipid phases are also destroyed [23], and a number of other disturbances caused. Regeneration is the process which normally heals any injury in a tissue, thus providing the repair when the causative agent has been eliminated. But the regeneration processes are particularly sensitive to ionizing radiation. Strelin and his co-workers have studied this aspect of ionizing radiation in detail. This work, which was carried out with various tissues and various biological objects, showed that the capacity to regenerate was depressed by ionizing radiation when the injuries were caused in any other way (mechanically or chemically).

All these considerations restrict the chances of using the reversibility criterion, which retains its value only for a limited number of phenomena. An important relation between the restorative capacity and the radiation dose must be noted here. In spite of the difficulty of estimating capacity to recover in a quantitative fashion, the data available enable us to assume that this relation is expressed by a S-shaped curve, the ordinate being the degree of reversibility of the changes in vital activities, and the abscissa the dose. We assume that the S-shape is due to two concurrent processes caused by the ionizing radiation. One of these is the change in the vital function at the various doses, the other being the changes in the restorative process. When drawing up the corresponding curves we should take the maximum value for the restorative processes as occurring at the natural radiation level (i.e., about $1 \cdot 10^{-11}$ r/day). The inflection on the S-curve lies in different dose ranges for the various vital activities: so the curves for the degrees of restoration of the various processes are displaced relative to one another along the abscissa.

In summing up the results of attempting to answer the question as to the importance to the performance of vital activities of the changes produced by small doses of ionizing radiation in tissues, we must point out the extreme vagueness of the problem. This obliges us to resort to considering certain special features of the relation between the organism and ionizing radiation, and to compare them with those shown with respect to other forms of energy in the environment.

The special relations between organisms and ionizing radiation are well illustrated by the small range of dose between those that cause the initial effects and those that cause the nonreversible changes in a given system of organs. For example, a distinct reaction is observed in the blood system at about 1 r, and irreversible injury to the blood-forming organs may occur at a dose of about 400 r. The serious changes in the blood-forming organs, which may lead on to leukemia, can in some cases arise after doses of 50 r. Thus, in some cases the range is 1:400, dropping to 1:50 in others.

One reason for this may be the absence of accommodation and adaption mechanisms, i.e., the capacity to counteract injuries which exist in relation to other forms of energy. This may be due to the natural radiation level, unlike other energy forms in the environment, being practically constant in magnitude. The light intensity at the earth's surface may change by factors of hundreds of thousands or millions during the course of the day. The amount of energy emitted by the human vocal apparatus varies by a factor of 10^6 in going from a whisper to fortissimo singing. Finally, both these examples presuppose adequate reactions on the part of the restricted systems in the organism. But, as with other general irritants - electric current, mechanical energy - the limits of permissible change are thousands and tens of thousands of times greater than the natural levels.

The present rise in the inherent level of radioactivity, which threatens to become still greater in future, impels us to be extremely active in evaluating the situation. Knowing well that the causes of these changes are the continuous nuclear weapons tests, we must use all possible ways of combating the existing hazard. It seems to us that all current scientific knowledge should impel scientists in all countries to support the humane demand of the Soviet Government that an international agreement on the cessation of further experimental explosions, should be concluded.

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ALL-UNION CONFERENCE ON THE APPLICATION OF
RADIOACTIVE AND STABLE ISOTOPES IN THE
NATIONAL ECONOMY AND SCIENCE

THE USE OF RADIOACTIVE ISOTOPES IN CLINICAL MEDICINE

A. V. Kozlova

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Editor

A. P. Belousov

Radioactive isotopes have been used for diagnostic and therapeutic purposes in the Soviet Union for not more than eight years. During this short period the methods of radioactive isotope diagnosis and therapy spread fairly widely through the clinics in various parts of the country. The effectiveness of the method attracted many specialists to this field, who started work even before all the requisite conditions had been established.

Radioactive isotopes found the most extensive application in internal medicine, endocrinology, dermatology and especially oncology, where isotopes have been incorporated into daily practice.

Sufficient experience has accumulated up to the present time concerning the use of isotopes in different fields of medicine, on the basis of which an attempt can be made to draw preliminary conclusions not only about the effectiveness of the method but also about the expediency and safety of its use, especially in those cases where isotopes are introduced into the patient's organism.

In recent years the question of the possibility of grave consequences following the use of isotopes has received much attention abroad. Reminders of the carcinogenic action of radioactivity have been growing louder and louder. It is essential for us to have our own point of view on this extremely important question.

It is well known that no less than 10-20 years are necessary to reveal the carcinogenic effect of radioactive substances in man; with only an eight year experience of isotope use we can not, as yet, submit proofs denying or confirming this possibility. However, we must decide already now to maintain the closest observation of those patients who had been subjected to isotope therapy; moreover, it is necessary to delimit more strictly the indications for the use of isotopes both for diagnostic and therapeutic purposes.

The use of isotopes in the clinical study of medical conditions contributed much that was new to the investigation of the pathogenesis of various diseases, and revealed the interaction of various organs and systems in the disorders of their functions. Practically, this has found expression in more precise diagnosis of diseases, which in turn has led to more exact indications for the various therapeutic measures and greater effectiveness of the therapy prescribed.

Radioactive iodine is the substance most extensively used in the diagnosis of various disorders. At first these investigations were directed principally towards the demonstration of disorders of the thyroid gland itself—thyrotoxicosis and hypothyroidism. The simplicity and availability of the method made its use possible not only in hospitals and therapeutic centers of the Union, but also under field conditions.

The numerous investigations carried out showed that the use of radioactive iodine in the diagnosis of thyrotoxicosis and various forms of thyroid disorders was a simpler and more precise method than the determination of basal metabolic rate and of iodine-containing protein in the blood used previously. Thus, for example, it is possible to differentiate between cases of alcoholism, increased nervous excitability, compensated hypertensive states and Parkinsonism, all accompanied by a raised metabolic rate, and cases of true hyperthyroidism by means of radioactive iodine. According to the data of Soviet and foreign workers it has not been possible to demonstrate a complete correspondence between the indicators of basal metabolic rate and iodine absorption by the thyroid, the latter being a more exact indication of the functional state of the gland. Another advantage of the use of radioactive iodine over the basal metabolic rate determination is that it is a method which characterizes the formation of the hormone. Basal metabolism is a consequence of the enhanced function of the gland.

The use of radioactive iodine becomes particularly valuable in the diagnosis of the more blurred forms of thyroid disorders, as well as in demonstrating thyroid dysfunction in other endocrine diseases in which clinical diagnostic methods did not give conclusive results.

Radioactive iodine also proved useful in the surgical treatment of thyrotoxicosis and goitres. The study of thyroid function following subtotal resection for thyrotoxicosis reveals relapses long before the appearance of

manifest clinical symptoms. Not infrequently this method revealed cases of retrosternal goitre.

Animal experiments using radioactive iodine have demonstrated that the synthesis of diiodotyrosine and thyroxine can occur in other tissues besides the thyroid. Thyroidectomized and hypophysectomized rats were given radioactive inorganic iodine. After 24-96 hours 30% of the labelled iodine could be found in the small intestine and the liver as organic iodine, viz. diiodotyrosine and thyroxine.

How difficult can be the diagnosis of thyroid pathology can be seen from the data of Z. I. Rozhnova and K. I. Kalinina showing that of 400 patients referred for investigation with a diagnosis of hyperthyroidism increased thyroid function was found only in 54%, decreased activity in 4% and normal activity in 42% of the patients. It should be noted at the same time that in a small number of cases normal radioactive iodine absorption is encountered in patients with manifest hyperthyroidism. On the other hand patients with clinically established euthyroidism show increased iodine absorption in rare cases.

In the assessment of the thyroid function it should not be forgotten that diseases of some of the internal organs may affect the rate of absorption and the total content of radioactive iodine in the thyroid. Thus, the excretion of radioactive iodine by the kidneys is impaired in cases of renal dysfunction and circulatory disorders. The rate of absorption of radioactive iodine and its total absorption are appreciably lowered after the administration of certain therapeutic substances such as, for example, thiouracil, or compounds containing iodine.

The iodine content of foods is not great and therefore a most varied diet, including iodized salt, exerts very little effect on the rate and total absorption of iodine by the thyroid. Greer and Astwood investigated the effect of 61 foodstuffs (independently of their iodine content); it was shown that cabbage, strawberries, carrots, spinach, oysters and milk lower the rate of iodine absorption.

Investigations indicate that the patients' age affects the rate of radioactive iodine absorption. The rate of iodine accumulation in middle aged patients is twice that observed in elderly patients. The rate of accumulation is 0.5-1.4 times higher in women than in men of the same age.

Therefore a number of factors which appreciably affect the total absorption and the rate of accumulation of iodine must be borne in mind in assessing the functional state of the thyroid.

Numerous studies made in the Soviet Union have shown the close functional connection between the thyroid and the internal organs. Thus, for example, there is an obvious connection between the thyroid and the cardiovascular system. This is inferred by the effect of the thyroid hormone on the different aspects of metabolism, which doubtless affects the function of the cardiovascular system. Disorders of the cardiovascular system, in their turn, may produce thyroid dysfunction (lowering of its activity) by way of circulatory impairment. In connection with this, the study of thyroid function in cardiovascular diseases gives much valuable data for diagnosis, determining more precisely the phase and stage of the disorder.

M. N. Fateeva, K. L. Georgadze and others have demonstrated some increase of radioactive iodine absorption in the first stage of hypertensive disease and a decrease of its absorption in the third stage, which is explained by profound disorders of circulation. Parallel changes in the indicators of thyroid function and basal metabolism were only observed in the first stage of the disease. As the disease progresses, thyroid function decreases while basal metabolism indicators show a rise. Thyroid hypofunction in the sclerotic stage of hypertensive disease should be regarded as a compensatory state. Patients with rheumatic heart conditions (compensated stage) most frequently show normal rate of absorption and normal accumulation of iodine. When the rheumatic process becomes more acute the accumulation of iodine in the thyroid increases, which corresponds to the clinical picture of mild hyperthyroidism. Cardiac decompensation is accompanied by marked lowering of the rate of absorption and the total content of iodine. Changes in the rate of iodine absorption can be demonstrated much earlier than the appearance of clinical symptoms, which is very important from the point of view of prophylaxis and the earliest possible treatment of the condition. Of no less importance, diagnostically, has been the use of radioactive iodine in the differential diagnosis of functional and atherosclerotic cardiac impairment. In the first case there is little impairment of thyroid function. Lowering of thyroid function is seen regularly in atherosclerosis. At the same time, other methods, even electrocardiography, often do not make it possible to arrive at the correct diagnosis.

Increased absorption of radioactive iodine is also seen in exacerbations of tuberculosis, in encephalitis,

diencephalitis, post-concussional syndrome and pregnancy (E. I. Tikhonova et al). The iodine-absorption curve in these cases differs markedly from the absorption curve in hyperthyroidisms. No changes in basal metabolism occur in these cases.

A marked connection between thyroid function and the state of the kidneys has been demonstrated. L. I. Kazakova's work showed that increased thyroid function is observed in nephritis; it becomes normal as renal function improves. Renal insufficiency is characterized by lowering of thyroid function.

Interesting data have been obtained in the studies of thyroid function in various dermatoses. Thus, F. I. Sukhovoy showed, using radioactive iodine, that in eczemas, even in the absence of clinical signs of thyroid dysfunction and with normal radioactive iodine absorption, insufficient formation and circulation of thyroid hormone can be presumed from the delayed excretion of the iodine.

The examples cited of the use of radioactive iodine in diagnostics make it possible to appreciate the value of this method of investigation.

A study of blood volume, erythrocyte volume, plasma volume and bleeding time has been made with the help of radioactive isotopes— ^{131}I , P^{32} , and Na^{24} —in connection with the diagnosis of cardiovascular disorders.

The determination of the circulating blood volume using radioactive phosphorus has been carried out in our clinics in various diseases. It has been established that in myocarditis and myocardiodystrophy, during the compensated stage the volume of circulating blood is decreased, with diminished total volume of erythrocytes and decreased amount of plasma; in M. N. Fateeva's view this can be explained by an adaptation reaction on the part of the organism, designed to lessen the work of the heart. When there is insufficiency of circulation developed as the result of cardiac failure, an increase of blood volume is observed with an increased amount of plasma and normal or even diminished erythrocyte volume. According to A. L. Mikhnev's data an appreciable lowering of blood volume of the oligocythemic type is observed in the first and second stages of hypertensive disease. In the third stage with circulatory insufficiency the blood volume approaches normal; M. N. Fateeva's findings show that in pernicious and hemolytic anemias the blood volume decreases while in myelomatosis and lymphadenomatosis it is increased.

Studies of the permeability of erythrocytes to radioactive phosphorus showed that in different diseases, such as endarteritis obliterans as well as in polyarthritis and some forms of tuberculosis, the erythrocyte permeability is increased; in chronic nephritides and cirrhosis of the liver it is decreased.

The study of hemodynamics in patients with cardiovascular diseases and with diseases of the lungs, liver and peripheral blood vessels is of great practical importance. The use of isotopes for this purpose has made this method available for wide application. The rate of blood flow both in the greater and lesser circulations has been determined in the various stages of hypertensive disease, in rheumatic heart diseases, cardiac failures and in diseases of the lungs and liver. A definite slowing of the rate of blood flow has been demonstrated in disorders complicated by cardiovascular insufficiency.

Methods for the determination of the rate of blood flow and of blood volume (which characterize the compensatory functions of the organism) should find extensive application not only in the field of internal medicine but also in surgery, to disclose the functional state of the cardiovascular system prior to major operative procedures, which could give valuable data as regards indications and contra-indications for surgical intervention. Of no less importance are data obtained in the postoperative period which can reveal the state of the patient's compensatory mechanisms.

It has proved to be possible to determine the rate of tissue blood flow, both from the tissues into the blood stream and from the blood stream into the tissues with the help of radioactive isotopes, radioactive sodium in particular. The rate of tissue blood flow cannot be equated with capillary permeability. The latter affects the rate of passage of radioactive substance from the capillaries into the tissues. The passage of the radioactive substance from the tissues into the blood stream is determined, evidently, by other factors as well, since there are states in which increased permeability of the capillaries is associated with slower penetration of the radioactive substance into the blood stream, as for example in shock.

Clinical observations have indicated that the development of cardiovascular insufficiency leads to slowing of tissue blood flow, with a definite interrelation of the degree of insufficiency and slowing of the blood

flow. Subjects with compensated heart failure show normal rate of tissue blood flow, which decreases on the appearance of incipient edema; the resorption of sodium almost completely ceases in patients with severe circulatory insufficiency. The diagnostic importance of this method lies in the possibility of revealing early states of decompensation which may not be recognizable by other clinical methods of investigation; it can moreover, serve as a test of the effectiveness of therapeutic measures.

The rate of blood flow in rheumatism depends not only on hemodynamics but also on the permeability of the capillaries and connective tissue; therefore, complete correspondence between the degree of decompensation and slowing of sodium resorption has not been observed.

The study of capillary permeability by means of radioactive isotopes allows the determination of the state of histohematic barriers in the organism and of the rate of passage of electrolytes from the blood into the tissues and from the tissues into the blood which is of great importance in assessing the water balance of the organism.

Studies of the hematoophthalmic barrier revealed its dependence on the functional state of the visual apparatus.

N. N. Zaiko has shown that the blood vessels of the middle ear possess barrier function. The hemato-lymph barrier assures a constant composition of endo- and perilymph which is essential for the proper functioning of the auditory apparatus.

The indicator method has also confirmed the existence of barrier function in the vessels of the joints. This barrier is impaired in inflammation, trauma and disturbances of joint innervation.

Studies of the rate of blood flow and of tissue blood flow have proved to be very useful in surgery. Thus the study of peripheral circulation by means of radioactive sodium in such diseases as arteritis obliterans has proved to be exceptionally valuable in following the dynamics of the process.

In orthopedic practice the study of peripheral circulation has proved very useful in investigating circulation in the stump both at rest and during movement; peculiar changes have been observed which must be regarded as signs of adaptation. Studies of local circulation in the stump have led to rational recommendations concerning the making of prosthetic appliances (V. N. Boyarskaya). The use of radioactive isotopes permitted V. A. Polyakov to obtain valuable data on the processes of consolidation in compound and simple fractures of bones. The author showed that the mineral substances used in the formation of the bone callus are not derived from the ends of the broken fragments but from the whole organism, and moreover that these mineral substances are derived from the external environment.

Radioactive isotopes proved to be useful in the diagnosis of malignant tumors in cases where biopsy was difficult or dangerous for the patient, as for example in tumors of the eye, in malignant melanomata and cerebral tumors. The increased absorption of radioactive phosphorus and iodine by rapidly growing tissues, such as are encountered in malignant tumors, permits their detection by means of special counters and so assists in the differential diagnosis of malignant growth and inflammatory processes.

The examples cited of the diagnostic use of radioactive isotopes indicate their undoubted value and usefulness which have placed the diagnosis of various diseases on a very high level indeed.

In evaluating this method of investigation from the point of view of its safety we must emphasize that we, contrary to foreign workers, have found no serious grounds for alarm. As is well known, in foreign practice not only the short-lived radioactive isotopes but also those with a very long half-life period are used, among them Fe^{59} ($\tau = 47$ days), S^{35} ($\tau = 88$ days), Na^{22} ($\tau = 1100$ days), Fe^{55} ($\tau = 1500$ days) and C^{14} ($\tau = 1.7 \cdot 10^4$ days). Moreover, the magnitude of indicator doses used abroad is tens of times greater than that of doses used in the Soviet Union. The introduction of isotopes with a long half-life period into the organism is always hazardous with respect to their carcinogenic action.

The Soviet Ministry of Health has prudently forbidden the use of long-lived isotopes. The use of minute doses of short-lived isotopes for diagnostic purposes cannot, most probably, exert any appreciable harmful effect. And still it would seem advisable to keep a record of all the patients who had received radioactive isotopes for diagnostic purposes in order to trace their state of health over a period of at least 10-15 years. At the same time it is essential to limit the use of isotopes in certain age groups, namely after 40 years. Taking into account the

high sensitivity of the organism to ionizing radiation in childhood, methods of investigation using radioactive isotopes should not be applied to children. Radioactive isotopes should be used therapeutically in children only in cases of such diseases as the leukemias, in which the expectation of life with any of the others methods of treatment does not exceed a few years.

The use of radioactive phosphorus for the treatment of anemias, leucopenias or other diseases is absolutely impermissible. Unfortunately it is so used in isolated therapeutic centers.

Radioactive isotopes have found the greatest therapeutic application in the treatment of thyrotoxicosis, some forms of disorders of the blood-forming organs, in dermatology, and especially in oncology.

In the course of the course of the last two years 2448 patients with thyrotoxicosis have been treated in the therapeutic centers of Moscow, Kiev, Sverdlovsk, Chelyabinsk and Stanislav. The disease was in the first stage in 9% of the cases, in the second stage in 46% and in the third in 45%, i.e., the patients had predominantly medium to severe forms of thyrotoxicosis. The majority showed diffuse goiters. The treatment was carried out in the main according to the fractional method in which the patient is given 2-3mC of radioactive iodine three seven times with intervals of six eight days; the total dose varied between 4 and 20 mC. Much more rarely a single dose of 6-10 mC was given.

Analysis of the material shows that both methods of treatment give a fairly high percentage of cures or considerable improvement; it varies between 61 and 90%. The percentage of cures with single doses of radioactive iodine reaches 81-90%. (Material from the Moscow Endocrinological Institute — 800 patients, from the Stanislav Goitre Clinic — 290 patients).

In the case of the fractional method of treatment as carried out in various therapeutic centers the percentage of cures varies within wider limits — from 51 to 88%. With both methods the patients were followed up for three months to three years. Relapses were observed more frequently following fractional treatment and occurred in 26 to 12%. Complications in the form of hypothyroidism occurred more frequently with single doses of radioactive iodine. In the majority of cases the hypothyroidism was transitory.

We should like to draw attention to the inadequate consideration of the age of the patients subjected to radioactive iodine therapy. In many centers this treatment was given to patients aged from 20 to 60 years. Taking into account the high degree of radiosensitivity of tissues in the younger age groups, radioactive iodine treatment should be recommended for patients over 40 years of age, the younger ones being given other forms of treatment.

Radioactive phosphorus has been used for the treatment of blood disorders. The best results have been obtained in the case of erythremias. As is known, radioactive phosphorus therapy is used in most centers only in the later stages of the illness when medication and bloodletting cease to be effective. The universally accepted procedure is to give radioactive phosphorus (internally) in the dose of 2 mC two-three times with intervals of six eight days directly after bloodletting. As shown by N. V. Nikolaeva, with this type of procedure it is often sufficient to give 4-6 mC of radioactive phosphorus in order to obtain a therapeutic effect.

In the last five years 201 patients with erythremia have been treated in the research institutes of Moscow and Leningrad and in the clinics of the Sverdlovsk and Chelyabinsk Medical Institutes. Of these, 177 were given one course of treatment and 24 were given two courses on account of relapses (Table 1). The results of radioactive phosphorus therapy proved to be much better than those of drug treatment and roentgenotherapy formerly used.

Less favorable results are obtained in the radioactive phosphorus treatment of patients with leukemia. Analysis of available data permits the recommendation in the majority of cases of lymphoid and myeloid leukemia of combined methods of treatment, including roentgenotherapy, blood transfusion, radioactive phosphorus, vitamin therapy and other measures. Even these complex methods of treatment, however, do not result in cure. The use of radioactive phosphorus in combination with other therapeutic measures leads to longer remissions, reaching three years in isolated cases, chiefly in the myeloid form of leukemia. In the case of the lymphoid form of leukemia the prospects for the use of radioactive phosphorus are still less encouraging.

Radioactive isotopes have been used without success in dermatology. Radioactive phosphorus in the form of external applications has received the most extensive application in this field. It has the advantage, in treatment of skin conditions, of the small penetrating capacity of its β - radiation, which does not exceed 3-4 mm in the tissues.

TABLE 1

Results of Radioactive Phosphorus Treatment of Patients with Erythremia from the Materials of Moscow, Leningrad, Sverdlovsk and Chelyabinsk Therapeutic Centers

Number of patients	Number of courses of treatment		Duration of remissions			
	1	2 and more	6-12 months	1-4 years	4-6 years	No Information
201	177	24	87	72	26	10

TABLE 2

Results of Treatment of Patients with Leukemia from Materials of the Moscow, Leningrad, Sverdlovsk and Chelyabinsk Therapeutic Centers

Number of patients	Results of treatment		Duration of remissions			
	Improvement	No Improvement	1-6 months	6-12 months	1-1.5 years	2-3, 5 years
198	140	58	53	55	30	2

Relapses after seemingly successful treatment by various means, including radiation, are characteristic of many skin diseases. Taking this into account, it is extremely important that radiation should only affect the surface layers of the skin without causing sclerosis of the underlying tissues.

The earliest application of radioactive phosphorus was in cases of flat capillary angiomata frequently seen on the face, often involving half or the whole face. Prior to the use of isotopes no treatment was available except in cases with minimal involvement.

The introduction of radioactive phosphorus has permitted the treatment of these patients. The results can be considered as completely satisfactory.

Analysis of the results of treatment of patients (845) seen only in the clinics of provincial towns of the USSR shows considerable improvement in 50 to 90% (average 63.6%), insufficient effect in 31.7% and complications in 4.7% of the cases.

Complete disappearance of the lesions was only observed in small children; in adults the lesions usually became noticeably paler.

Radioactive phosphorus proved successful in the treatment of eczemas, neurodermatitis and pyoderma.

From pooled data of 470 patients with neurodermatitis, 75% were cured.

TABLE 3

Use of Radioactive Phosphorus in Skin Diseases. Period of Observation from One to Four Years.

Diagnosis	Number of patients	Cure				Relapses
		Percentage	Percentage	Percentage	Percentage	
Capillary angiomata	945	7	63.6	29.4	—	—
Neurodermatitis	470	75	—	25	19	—
Eczema	1244	85	—	15	23	—

Treatment of 1244 patients with eczema resulted in cures in 85%; in 15% the treatment proved ineffective and relapses occurred in 23% of the patients.

Radioactive phosphorus has become firmly established in the treatment of capillary angiomata, neurodermatitis and eczema, and is used not only in central therapeutic establishments but equally widely in regional clinics. This convenient and simple method of treatment can find even more extensive application when a

radiating isotope applicators are manufactured on a commercial scale. In this case it is expedient to use isotopes with a longer half-life period, such as strontium, yttrium and cerium.

As already mentioned, the most important use of isotopes has been in oncology. Radioactive cobalt is most frequently used for the treatment of patients with malignant tumors; radioactive gold and iodine are used much more rarely. The use of isotopes in the treatment of malignant growths has led to appreciable improvement of results. The main reasons for such a change are the following.

In the first place it has become possible to use radioactive preparations extensively for the treatment of patients with malignant tumors. Before radioactive cobalt became available to oncological centers natural radioactive substances — radium and mesothorium — were used for therapeutic purposes. However, these substances were only available in a few central oncological establishments; the majority of oncological departments throughout the country employed surgery in combination with roentgenotherapy.

In the second place, of great advantage has been the construction of γ -installations with powerful sources made of radioactive cobalt. The use of tele- γ -therapy opened up new possibilities of treatment of patients with malignant tumors of internal organs who had not, prior to this development, been subjected to radiation therapy at all.

And finally, in the third place, a no less important advantage of isotopes is the possibility of introducing short-lived isotopes into the patient's organism in those cases where surface irradiation is either impossible or unpromising. This latter development has led to considerable extension of indications for radiation therapy in the case of gravely ill patients for whom no specific treatment was previously available.

We shall attempt to support these statements by factual material. We shall consider only those forms of malignant tumors whose treatment prior to the use of isotopes has been, in the majority of cases, unsuccessful.

Cancer of the female sex organs is one of the most frequently encountered forms of malignant neoplasms. Both surgical and radiation methods of treatment are used in early cases, whose incidence still does not exceed 20-30%. The percentage of cures in various therapeutic centers reaches 70. Treatment of patients with more severe forms of the disease and especially with diffuse extension of tumor to the pelvic lymph nodes leads to cure in not more than 10-15% of cases, using both the surgical and the combined as well as purely radiational methods of treatment (N. P. Dmukhovskaya, S. S. Dobrotin, E. P. Ivanitskaya). According to the data of the Roentgenological and Radiological Institutes in Moscow, Kiev and Leningrad the percentage of cures in the third stage of the disease has risen in recent years to 30-35%.

TABLE 4

Results of Radioactive Co^{60} Treatment of Cancer of the Cervix.

Roentgenological and Radiological Institute	Total Number of Patients	State of Disease								Length of Follow-up
		I		II		III		IV		
		Number of Patients	% Cured	Number of Patients	% Cured	Number of Patients	% Cured	Number of Patients	% Cured	
In Leningrad	502	53	90	196	64.3	249	35	4	—	1 to 3 years
In Moscow	91	—	—	—	—	91	35.1	—	—	5 years & more
In Kiev	221	12	66	65	65	122	35	22	—	1 to 5 years

Until quite recently patients with carcinoma of the lung who could not be treated surgically were only subjected to symptomatic medication. It should be remembered that of the number of all patients who seek help the percentage of those suitable for surgery does not exceed 10-15%. The length of survival of patients treated only symptomatically is not greater than six months.

Tele- γ -therapy in carcinoma of the lung has only been used fairly recently in certain institutes. The first results obtained permit the recommendation of this method for those patients who cannot be treated surgically, as it leads to resumption of working capacity and prolongation of life (Table 5).

In cancer of the oesophagus surgical treatment is possible in not more than 20-30% of the patients (V. I. Kazansky, L. G. Savinykh and others).

TABLE 5

Results of Tele- γ -therapy in Carcinoma of the Lung from Materials of the V. M. Molotov Roentgenological and Radiological Institute.

Number of Patients	Stage of Disease	Length of Survival					Above 5	No information
		1 Year	Up to 2 years	Up to 3 years	Up to 4 years	Up to 5 years		
56	III-IV	20	16	6	3	6	2	3

The method of treatment developed in the V. M. Molotov Roentgenological and Radiological Institute, which consists of the combination of tele- γ -therapy with an intra-oesophageal method of treatment allows food to pass again through the oesophagus, improves the general condition and prolongs the life of the patients. It is well known that the expectation of life in patients with cancer of the oesophagus does not exceed a few months from the time of confirming the diagnosis.

TABLE 6

Results of Treatment of Cancer of the Oesophagus from Material of the V. M. Molotov Roentgenological and Radiological Institute.

Number of Patients	Stage of disease			Length of survival		
	II	III	IV	One Year	2	3
80	10	54	16	51	25	4

Cancer of the bladder is one of the frequently encountered forms of malignant neoplasms. Until recently only surgical treatment was used, with a high incidence of relapses. Patients unsuitable for surgery were not subjected to roentgenotherapy since it was ineffective.

Methods for the treatment of inoperable cancer of the bladder have been developed in recent years at the Moscow Roentgenological and Radiological Institute. A combined procedure was used: tele- γ -therapy supplemented with intra-tissue method of treatment by means of radioactive cobalt needles introduced into the tumor or application of a colloidal solution of radioactive gold to the opened bladder. In other cases tele- γ -therapy was combined with an intravesicular method of treatment using radioactive sodium solution.

The results obtained show that isotopes provide effective treatment in cases of inoperable cancer of the bladder (Table 7).

TABLE 7

Results of Treatment of Cancer of the Bladder.

Roentgenological and Radiological Institute	Number of Patients	Stage of disease				Result of treatment			Negative result
		I	II	III	IV	Freedom from symptoms and restoration of working capacity.			
						1—2 years	2—3	Over 3	
In Moscow (the V. M. Molotov)	174	16	130	28	9	96	29	40	
In Leningrad	183	15	160	8	29	116	4	34	
Total	357	31	290	36	38	212	33	74	

Until recently cancer of the breast has been treated by a combined method consisting of radical mastectomy and preoperative and postoperative roentgenotherapy. An intra-tissue method of treatment has been

developed at the P. A. Gertsen Oncological Institute in Moscow which consists of the insertion of radioactive cobalt or radium needles after the removal of the tumor sparing the breast. The results obtained are not inferior to those of surgical treatment (Table 8).

TABLE 8

Results of Intra-tissue Method of Curiotherapy from Material of the P. A. Gertsen Oncological Institute.

Number of Patients	Stage of disease			Healthy			Total
	I	II	III	1-2 years	3-5	6-9	
99	31	60	8	14	26	27	67-66%

Failure of treatment in cases of malignant tumors very often depends on the appearance of metastases in the absence of relapse at the primary focus. Until the use of isotopes treatment of metastases was usually condemned to failure. The use of telegammatherapy, of radioactive solutions and preparations has made it possible to obtain satisfactory results in these severe forms of neoplastic disease.

TABLE 9

Results of Radiation Therapy in Metastases of Various Localization (Submandibular, Cervical, Supraclavicular, Groin Lymph Nodes).

Therapeutic center	Number of patients	Results of treatment		Length of follow-up
		Healthy	% Cures	
The P. A. Gertsen Oncological Institute	581	168	28%	From 1 year to 6 years
The V. M. Molotov Roentgenological and Radiological Institute	107	52	48%	From 1 year to 7 years

The use of colloidal radioactive gold solution allows treatment of patients with what would appear to be hopeless conditions and who are unsuitable for the usual methods of radiation therapy.

Thus, according to the materials of the V. M. Molotov Roentgenological and Radiological Institute, of 87 patients of whom 22 had metastases of malignant melanoma and 65 relapses and metastases with various localizations satisfactory results were achieved in 50; cessation of growth of the tumor, disappearance of pain and improvement of the general state for a period of from one to four years.

The examples cited here, illustrating the results of treatment of the most severe forms of malignant neoplasms in which until recently treatment was completely unsuccessful, indicate convincingly the extension of therapeutic possibilities associated with the introduction of radioactive isotope treatment.

The possibilities of the clinical use of radioactive isotopes are still far from having been exhausted.

The further development of therapeutic methods using isotopes should follow four main directions.

1. Construction and manufacture of new powerful gamma-installations both of the stationary and rotary type.
2. Manufacture of various types of radioactive devices for radiosurgical methods of treatment.
3. Manufacture of colloidal solutions of various radioactive isotopes and also of devices for their introduction.
4. Serial manufacture of special apparatus designed for the diagnostic use of isotopes.

The variety of methods of isotope therapy makes it possible to take into account the individual peculiarities of each case, which leads to a considerable increase in the number of cures.

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DEPARTMENT OF ATOMIC ENERGY UTILIZATION,
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ALL-UNION CONFERENCE ON THE APPLICATION OF
RADIOACTIVE AND STABLE ISOTOPES IN THE
NATIONAL ECONOMY AND SCIENCE

ISOTOPES AND RADIATIONS IN AGRONOMY

V. M. Klechkovsky

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Progress in the agricultural sciences is very closely connected with the development of general knowledge of nature and with progress in physics and chemistry in particular. As these sciences and the industrial processes related to them have developed, new ways of performing scientific experiments have been produced which have deepened our theoretical understanding in agronomy, just as in biology, medicine and a number of other branches of science.

Engels, commenting on the role of production in the development of science, noted the importance of the body of fresh mechanical, chemical and physical facts accumulated during the development of industry, which is not only basic material for scientific observation, but also provides completely new ways of carrying out experiments and constructing instruments which did not formerly exist [1]. Timiryazev has emphasized the great importance of the experimental methods of physics and chemistry when applied to physiological problems. "One may say" he writes in his review of the development of biology in the 19th century "that all the brilliant advances in physiology were closely connected with the application of physical and chemical methods to the more complex and detailed problems of physiology, these methods frequently being ingeniously refined in the process. The rule is here again proved that the discovery of new research methods is frequently the source of more notable progress than is the acceptance of a new theory or a fresh compilation of facts" [2]. This evaluation of the role of new experimental research methods which arise in the course of development of our general knowledge of nature and of industry, and of their importance to physiology, and hence agronomy also, is very applicable to the present time, when a rapid technological revolution is occurring with an unceasing extension of opportunities for scientific experiment, due mainly to progress in nuclear physics and current atomic physics in general.

Agriculture is at present the widest field for the application of scientific and technical achievements. The application of industrial techniques to agriculture on a large scale, using the various scientific research methods in agronomic work, will, in its turn, exert an important influence on the development of science and technology.

But we must remember that the relation between science and production in agriculture is different from that in other branches of industry, which latter could not have developed without the prior development of the various scientific disciplines (e.g., electrical technology or atomic industry).

Agriculture developed historically long before any exact scientific experiments existed. And only gradually, hand in hand with the development of our knowledge of nature, did the enormous practical experiment that is agriculture become the object of study and scientific generalization. At this stage agriculture science did not provide the prerequisite for a new industry to arise, but existing practice was merely systematized and rationalized.

We would need to say no more about this relation between science and production in agriculture today were it not that this relation sometimes is not apparent even now. As was remarked above, since science is less responsible for the development of agriculture, the ground was laid for the occurrence of various dogmatic doctrines in agronomy, the unoriginal deductions of which are of little assistance or are even a hindrance in practice.

As the exact sciences have developed and been widely applied in agronomy the field open to dogmatic doctrine has been further and further reduced. In addition, the attachment of agriculture to industry has provided a sounder basis for the increase of the scientific influence in agriculture.

The large part played in cultivation, at its present technological level, by the chemical industry and agro-chemistry, for instance, is well-known: this has occurred by the application of chemical knowledge and chemical methods to agricultural questions: e.g., of chemical theories to the feeding of plants and of chemical conditions for soil fertilization; it has given an agronomic basis to the production of industrial fertilizers, and a

scientific basis for the correct application of fertilizers has developed and continues to develop.

But the development of agrochemistry and agronomy in general is indissolubly linked with the progress of general chemistry, physical chemistry, biochemistry and physiology, with the constant enrichment of agronomy by new theoretical concepts and new means of experiment. Hence Timiryazev's noteworthy comment [3] that "current cultivation has become what it is only because of agrochemistry and plant physiology" must be considered not only as a profound evaluation of the role of active scientific intervention in agriculture, but also as applying to the direct connection between agronomy and scientific knowledge. Only by working to extend our knowledge of the processes of agriculture, using all the best methods currently available, can we ensure the required development of agronomic science free from tendencies to dogmatic scholasticism. Only when agronomy is closely connected with general scientific knowledge can we use completely the fresh techniques which have developed together with new industries.

In our day, when humanity has attained the atomic age, new atomic techniques are being rapidly developed and introduced into the most varied branches of science and technology. Progress in nuclear physics and isotope chemistry, which has been crowned by the production of nuclear power, has revealed a wide field for the application of atomic techniques in agriculture and agronomic research.

One of the main items in this arsenal of techniques is the use of isotopes of various chemical elements and a variety of forms of nuclear radiation. γ -rays, β -particles of various energies, and fast and slow neutrons have become readily accessible means for research and for practical use of their action on organisms, including microorganisms, higher plants and animals. This action may be utilized to alter the genetic properties of the organisms in order to increase their productivity; it can be used as a means of regulating the rates of biochemical processes, and as a disinfecting or sterilizing agent. Nuclear radiation sources are widely used for producing new equipment for use in agricultural experiments.

The production and use of atomic energy results in the formation of an enormous amount of radioactive materials (fission products from heavy nuclei). Fission products, together with some other radiation sources (such as Co^{60}) are the most accessible forms of radioactive material for use as radiation sources in agriculture, e.g., for radiation disinfection, etc. But this does not restrict the body of agricultural problems which arises in connection with fission product formation (when atomic energy is produced). These fission products are the radioactive isotopes of elements (strontium, ruthenium, cesium, cerium, etc.) which formerly had been almost completely or even completely neglected in agricultural science. Agronomy is at present faced with the serious problem of studying the actions of fission products on plants and of elucidating the laws which govern the rates of the long-lived fission products when these enter the agricultural circulation of matter. These laws must be studied so that scientifically sound protective measures can be taken to prevent the undesirable consequences of radioactive materials accumulating in agricultural products. Investigation of all these problems will give rise to essentially new branches of agronomic science, such as radioisotope agrochemistry and agricultural biophysics.

There is no doubt that the vast increase in power sources produced by the inexhaustible sources of nuclear energy will in the future prove of great importance not only to industry and transport but also to agriculture. But at the present the problem of using atomic energy occupies no obvious place in agricultural science, this is for the future. At the present time the practical use of atomic energy in agriculture lies predominantly in the use of isotopes and radiations as new means of scientific experiment.

The use of isotopes and radiations in agronomic research has extended considerably in recent years. And if today we can say that some important practical problem has been solved on this basis we can assert with complete confidence that many partial questions of practical importance have had new light thrown on them by the use of isotopes. In addition, the use of isotopes has assumed a very important part in work on a number of theoretical problems directly related to agronomy.

When evaluating these successes we must allow for the fact that the history of the use of isotopes and radiations in agriculture is as yet comparatively short. The initial stage of using atomic techniques in agronomic research was characterized by the posing of comparatively simple problems from which the utility of the new methods could be tested. But at the same time we must remark on the tendency which appeared in some work, which was to find some quick direct way of raising the productivity of cultivation (and livestock production) by using atomic techniques, e.g., by using the stimulant action of radioactive substance and nuclear radiations, and

thus hoping to obtain results of importance in practice.

But it has now become clear that progress in this direction cannot be considered as a light task, either with regard to the use of isotope methods in agronomic research or the direct action of nuclear radiations on organisms; very careful systematic detailed work is required. For this purpose a number of important methodological questions have to be resolved in using radiations and isotope methods for dealing with problems in agronomic science.

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Passing now to a review of the ways of using radiations and isotope methods in agronomy which have so far been defined, we must first expound some results obtained by using tracer methods for research on the most important biochemical processes on which agriculture is based. The first of these is photosynthesis.

Vinogradov [4] was the first to determine the isotope composition of the oxygen evolved by plants during photosynthesis; he concluded that the photosynthetic oxygen was derived from water and not from CO_2 . As radioactive carbon was used for this research on photosynthesis, we now have a profound knowledge of the chemistry of this process in the successive links of which the carbon is incorporated; the organic compounds are formed which provide the precursors for the synthesis of all the compounds which go to make up the organs of the plants and the formation of produce. Work using radioactive carbon and stable nitrogen isotopes has shown that there are effects, caused by the spectral composition of the light and other factors, which exert an influence on the course of photosynthesis and the routes taken by the primary accumulation of materials formed in photosynthesis. This work has provided agronomic science with new theoretical concepts as to ways of controlling the most important processes, such as photosynthesis [5].

The use of radioactive and stable isotopes in work on the absorption and metabolism of materials in plants has led to discoveries which provide a deeper insight into the mechanisms of the primary processes by which the elements taken up by the plant roots are incorporated, and which elucidate some important aspects of the relation between root feeding and carbon uptake by the plant. Tracer methods have revealed the part played by the root carbon dioxide in the formation of acceptors required for the binding of inorganic nitrogen compounds and the synthesis of amino acids; new light has also been cast on the factors defining the oxygen metabolism of plant organs, as related to the carbon dioxide sources used in photosynthesis [6].

New data has been obtained by tracer methods on the relation between photosynthesis, mineral absorption, and root synthetic activity; these are of great interest as applied to the adjustment of plant nutrition, and in relation to research on the external environmental factors which influence metabolism, growth and development. One of the basic general concepts of contemporary science in the field of plant nutrition, which was developed by D. N. Pryanishnikov [7], is that there is a close connection between external factors and the metabolic processes in plants, found by the use of radioactive and stable isotopes and new methods of research. This concept has been given a deeper concrete content.

The use of isotopic methods has led to the discovery of the continuous rapid turnover process which occurs in the plant proteins, nucleic acids and nucleoproteins. Using stable nitrogen and radioactive carbon isotopes it has been shown that chlorophyll turns over rapidly in plant leaves [8, 9]. Tracer methods have lately been used for research on the fixation of atmospheric nitrogen in bean-root tumors and have given the unexpected result that the nitrogen is not fixed in the bacterial cells but in the surrounding root cells [10].

Isotopic tracers were successfully used in work on the transfer and exchange of materials between graft and host in plant grafting, for research on the relations between the separate parts of the root system in fruit trees [11] and for elucidating the role of the various roots in the uptake of nutritional elements in grasses. Some features of the uptake of phosphorus from the external medium during the initial phase of growth and development were established; new data on the relation between phosphorus uptake and state of nitrogen nutrition were obtained. Isotope methods were successfully used in work on the effect on uptake of mineral elements of the development of root microorganisms [12].

The use of isotope methods in research on the non-root (leaf) nutrition of plants appears to be very desirable. By using isotopic labels it was possible to carry out accurate detailed observations on uptake processes during non-root nutrition, on the participation of the materials in metabolism and on their removal to other

parts of the plant from the treated leaves [13]. The use of isotope methods to study non-root nutrition is well known to facilitate experiments on the efficiency of this type of nutrition in cotton plants, sugar beets and other agricultural crops, and it has given an impetus to the general field testing of this method in our country.

Tracer methods have been fairly widely used in experiments on the efficiency of various methods and times of fertilizer application to the soil, mainly with phosphorus fertilizers. The advantage of this method of studying fertilizer problems is primarily due to the fact that the amounts of the element taken up from the labelled fertilizer and soil can be determined directly. In tracer phosphate experiments numerous facts were obtained of great interest in the practical use of phosphate fertilizers.

In experiments with labelled superphosphate the importance of fertilizer grain size was clearly demonstrated: this affects the phosphorus uptake at various growth periods - in particular fine granules were shown to be advantageous for providing phosphorus at the commencement of growth (the fertilizer being drilled in with the seed), and coarse granules being better during the subsequent vegetative period [14]. These results pose the problem of reconsidering the granular specifications for superphosphate given to industry.

Much attention has been given in agricultural experiments in recent years to certain methods of combining organic and superphosphate fertilizers, or organic fertilizers and lime. Isotope methods have provided very convincing objective data on the simultaneous application of superphosphate and organic fertilizers. It has also been shown what relations between the organic and mineral dressings have to be observed in order to give a positive advantage in phosphorus uptake. The rates and completeness with which plants use phosphate fertilizers when the fertilizers are used alone or in admixture with organic material were also discovered as well as the relation to the depth of drilling and site of application (in the rows, in holes or in pits). It was found, in particular, that to increase the phosphorus uptake from superphosphate it was sufficient to mix it with very much smaller amounts of organic material (humus) than usually recommended. It was found that the advantage of shallow drilling the superphosphate (or superphosphate - organic mixture) when a scattering technique was used existed only during the mutual growth period, and that fertilizer more deeply drilled (18 - 20 cm) was taken up better during almost the whole of the vegetative period, apart from a few days at the beginning. It was also confirmed that the best way of providing phosphorus was to combine the main application (at the bottom of the cultivated layer) with local applications of small amounts by dusting or depositing it in rows, holes or pits [15].

The use of isotope methods to determine the amount of nutritive material taken up from the fertilizer, together with chemical analysis of the plant material enables us to determine how much of that element taken up from the soil is derived from compounds naturally present in the soil or applied in earlier doses of fertilizer. Thus we may elucidate the effect of various modes of fertilization on the use of the plant makes of materials naturally present in the soil. The data are of great interest in dealing with questions relating to the correct fertilizer application system during crop rotations and in developing more efficient ways of using fertilizers.

We should also point out that isotope methods enable us to determine the uptake from various forms of fertilizer directly if the isotope label can be introduced into the fertilizer during preparation. This method is not always convenient, however, e.g., when ground phosphate rock is used. Neutron irradiation of natural phosphates does not solve this problem satisfactorily, since the atoms may change their chemical states during activation [16], the induced activity being in a different chemical state from the rest of the rock. In this connection Sokolov's proposed method for comparative estimation of the availability of various fertilizer forms is of interest; this consists of using an isotopic trace, in the so-called 'selective absorption' method [17]. The concept on which this is based is that in using two different forms of fertilizer at the same time, one being labelled to a known activity and the other unlabelled, the unlabelled being compared with the labelled standard on the basis of the amount of label taken up by the plant from the standard.

Isotope methods have lately been further refined, advancing their use in comparative studies on the various times and methods of fertilization. It has been shown [8] that by using a simple scheme (in a field or laboratory experiment) the amount of an element present in a plant can be divided into more than the two fractions corresponding to uptake from soil and fertilizer. For example, when the basic application is combined with an application along rows or at the roots, the fractions derived from the soil, the basic fertilizer, the amount applied along the row, and the amounts applied at various periods to the roots can all be determined. This all extends the chances of getting results of value in practice by means of exact experiments which answer questions related to the scientific basis of rational fertilizer use in agriculture.

Tracer methods have also been used successfully for research on the processes whereby soils react with fertilizers, in connection with the absorption of phosphates by soils [19]. New methods of determining the capacities of soils to absorb materials have been developed and related to certain other properties of soils which are important in agriculture [20]. A new rapid method for estimating the quality of irrigation water, based on isotope methods, has been proposed in connection with the properties of irrigated soils [21]. Work in which isotope dilution was used to determine the amount of phosphorus taken up from soils is of great interest [22].

It is extremely necessary to elucidate some questions of principle regarding processes involving isotopes in general, and radioactive isotopes in particular, if isotope methods are to be used successfully in future agronomic and soil research. Two such important processes stand out at the present time. One is concerned with the differences in behavior of the isotopes of a given element which are related to their mass differences, in systems such as soil and plants.

The mass differences between the isotopes of the lightest elements (hydrogen in particular) exert an important influence on the chemical and physicochemical properties of compounds which differ in isotope composition. These differences affect the behavior of hydrogen isotopes in biological systems [23], which must be borne in mind in isotope experiments with this element.

With regard to the mass differences of isotopes of elements such as nitrogen, sulfur, calcium, etc., it has so far usually been assumed that the differences do not influence their behavior in biological experiments in a material fashion.

In this connection we may consider Vlasuk's sensational paper [24] which appeared in 1953, on experiments in which, it was stated "the radioactive isotopes of calcium and phosphorus are taken up 10 - 50 times more slowly by plants than are the stable isotopes of these elements." The astonishing part of this work was not the general deduction that the isotopes of an element behave differently, but that the differences observed in the rates of uptake were so astoundingly large. The same author (1955) described a hydroponic experiment with summer vetch in which the specific activity of the plant calcium (in various experiments) was either almost equal to, or two, four or five times less than, that of the nutrient solution. He concluded that Ca^{45} atoms "enter the plant at a different rate from those of the stable isotopes" [25]. It might appear that these data and conclusions should have attracted considerable attention since they cast doubt on the general applicability of tracer methods to uptake, transport and metabolic processes in plants. But we know of no work in which these conclusions have been considered critically on the basis of experimental data, although while they have not been generally acknowledged, they have also not been verified.*

N. I. Selertkova of this Laboratory in 1956 undertook some experiments analogous to those cited. Vetch, pea and tobacco plants were grown in sand cultures fed right from the start with a nutritive mixture containing Ca^{45} - labelled calcium. Determination of the specific activities of the calcium in nutritive mixtures and in various parts of the plant did not confirm the conclusion that there are sharp changes in the ratio between the calcium isotopes when they are taken up from the nutritive mixture into the plant, as found by Vlasuk [24, 25]. The deviations in the specific activities of the calcium from various test plants did not exceed the error of experiment, as found by repeated measurement of the specific activities of the calcium from the nutritive mixtures. Thus we conclude that the data cited are of dubious veracity as far as the difference between the rates of uptake for radioactive and non-radioactive isotopes of calcium. The difference in the properties of ions and molecules of differing isotopic composition as it may appear in conditions of agronomic experiment has not been settled, but it is evidently of real importance only under conditions where the accuracy demanded is enormously greater.

But the detailed study of isotope effects in biological systems is of great theoretical interest, and the problem must undoubtedly attract greater attention the more widely isotope methods are used and the greater becomes the demand for precise accuracy in the results obtained by these methods.

* We note that an analogous problem of the behavior of different isotopes of the same element in biological experiments has also received attention with regard to animal organisms. It has been stated [26] that when the balances for the radioactive and stable isotopes of cobalt are drawn up it is found that they do not behave in the same way: "While stable cobalt is taken up to the extent of 65 - 70 - 75%, radioactive cobalt is only taken up to the extent of 25 - 30%." Hence it was concluded that living cells react differently to different cobalt isotopes.

The second question of principle related to the use of tracer atoms in soil, agronomic and physiological research is that of the role of radiation effects which always occur to some degree when experiments are performed with radioactive isotopes. This question is closely related to the more general problem of the biological action of ionizing radiations in general.

The action of ionizing radiations in plants has a few aspects which we will deal with shortly in connection with the future prospects of using isotopes and radiations in agronomy.

Since radioisotopes are widely used in physiological, agronomic and soil research at the present time, the problem of the action of their radiations is of great importance, purely from the methodological point of view when they are used in nutritional mixtures or in soils and are taken up and accumulated by plant organs. If the use of radioisotope methods in such work is to be successful it must be verified that the activity levels used and the ionization doses given are such that the radiation does not materially distort the course of the processes investigated. For example, the specific activity of a labelled fertilizer must be such that irradiation does not influence the uptake in the root (or in the leaf in non-root feeding), or on the transfer, distribution and accumulation of the element in various parts of the plant. When metabolic processes in plants are studied with isotopic labels the specific activity of the labelling element or compound must not exceed a level such that the radiation causes, directly or indirectly, changes in the rates of the metabolic processes under study. In addition, when deciding on the specific activity of the starting material for use in such experiments one should always bear in mind the other side of the question, namely, that the activity level must be high enough for the activity measurements to be accurate with the minimum amount of activity to be expected in that experiment.

Up to now this question has been dealt with on the assumption that normal tracer doses of radioisotopes have no material effect on the biochemical and physiological processes in plant experiments. But the concept of a tracer dose is arbitrary and systematic studies should be carried out, from which the limits of tracer doses could be determined more accurately for typical conditions of agronomic or physiological experiments.

The literature data, even on a question as simple as the effect of the radiation from P^{32} on the uptake of phosphorus is very contradictory. On the other hand, in a number of experiments in which the specific activity of the fertilizer was varied over a very wide range there was no appreciable effect on the phosphorus uptake, whereas on the other hand, experiments have been described where even extremely low levels of activity caused certain changes in the phosphorus uptake [27].

The need for a detailed consideration of the limits of tracer, tolerance and destructive doses in isotope studies in agronomy cannot now be doubted. Work in our laboratory has provided data of interest both from methodological and more general radiobiological points of view.

Right from the start it was clear to us that a rational solution could only be obtained by a many-sided study of the general physiology of the actions of radioactive materials on plants, carried out over a wide range on concentrations and ionization doses. The results showed that doses at which clear signs of radiation damage appeared in higher plants in general lie far outside the limits of dose required when using the isotopes as tracers.

But the sensitivities of plants to radiation damage depend on many factors, so it would in general be incorrect to specify standard limits which are the same for all cases at tracer, tolerance and injurious levels in plants.

In addition to the non-uniformity in radiosensitivity of various plant forms, the sensitivity will obviously change with age. In the early phases the growth is most stable against the destructive action of radiation.

It has also been found that the sensitivities of plants to the destructive action of radioactive materials depend strongly on the nutritional conditions and other external factors. For example, plants supplied with insufficient phosphate appear to be much more sensitive to the destructive action of radioactive phosphorus than do plants with an adequate supply [28]. The disturbance to metabolic processes occasioned by shading or alteration in the water supply affects the radio-sensitivity by reducing the accumulation of photosynthetic products.

Specific questions of dosimetry in applying radioactive materials to particular plants are of much greater importance to the study of the action of the radioactive materials: so far these problems have been dealt with but little.

This implies that the actions of radioactive isotopes of various elements must be related to their chemical properties, since these determine how they become distributed in the organs and tissues of plants. In this connection, not only are the specific distributions of isotopes such as those of carbon, phosphorus, sulfur, calcium, cobalt, zinc, etc., of interest, but also those of isotopes of other elements, particularly fission products (strontium, zirconium, ruthenium, cesium, cerium, etc.). Some of these products can accumulate in considerable quantities in the reproductive organs, or, accumulating in the root system, are only transferred to the above-ground parts of the plant to a slight extent.

The different distributions of radioisotopes of the various elements in plants and their varied take-up rates will result in different radiation actions being exerted on the plant tissues when the external concentrations are the same. Important differences due to the type of decay and energies of the particles emitted will also be present. For example, when the maximum β -ray energy is small, a large fraction of the energy liberated in the decay of the radioactive material in the tissue will be absorbed completely, almost independently of the size and shape of the organ. When the β -ray energies are high, and particularly with isotopes giving γ -rays, the fraction of the energy which is absorbed by the organ which contains the isotope may be extremely small. This difference is most marked in higher plants due to their specific structures which have organs of small transverse cross section. For example, calculations show that the organs of a leaf of thickness 0.2 mm absorb only about 25% of the energy liberated by radiophosphorus present in the leaf [29].

Hence the radiation doses (expressed in physical roentgen equivalents or in rads/unit time) received from radioisotopes with high-energy radiations vary not only with the concentration in the organs but are also very strongly dependent on their size and shape.

One further factor, which formerly fell outside the field of view of workers dealing with the actions of radioactive substances on plants, is important here. If a considerable part of the energy liberated by a radioisotope is not liberated in the organ in which it is contained (e.g., a leaf) but in the surrounding medium, the radiation dose received by the organ is made up of two parts - one due to internal irradiation (i.e., due to decay occurring within the organ) and the second due to external irradiation i.e., due to irradiation from adjacent organs and plants. This external irradiation, particularly in the case of γ -emitters, is determined not only by the shapes and sizes of the organs of the plant, but also on those of the plant assembly in which it is present.

For example, if there is one plant per pot, or several plants, each of which contain the same amount of some isotope emitting hard β -rays or γ -rays, then the organs of a single plant will receive a lower dose-rate (rads/sec) than those of a plant which is one of several growing in the same pot. If there are several such identical pots with plants containing the same amount of isotope, the external radiation field will increase yet further due to the adjacent pots, and hence the dose received by each plant separately will increase.

Thus, even in experiments with the same radioactive isotopes at the same concentrations in the feed medium, and with the same rate of uptake into the plant and identical distributions in the plant organs, the dose conditions may be far from equal. Neglect of the "radiation assembly" factor must be particularly borne in mind when comparing pot and field experiments if the isotope used emits γ -rays.

The circumstances considered briefly here are important in work on processes related to the biological actions of radioactive materials in their agronomic aspects, and also in problems related to the agrochemistry of fission products.

As it is not possible within the scope of this review to consider the complex array of problems in current agricultural science, I shall give only one example to show what special phenomena and specific problems are encountered in isotope agrochemistry and agricultural biophysics when the actions of radioactive substances in general are studied; and of the behavior in soils and actions on plants of fission products in particular.

Gulyakin and Seletkova [32] have shown that when elements such as radiothorium are taken up via the roots of plants the activity of the above-ground organs appears to be almost entirely due to the accumulation of short-lived daughter elements (thorium X and thorium B) rather than of the parent radiothorium, which

* A detailed discussion of the behavior of fission products in soils, their uptake by plants and accumulation in crops has recently been published by Kl'chikovskiy, Gulyakin et al [30]. For a general review of the literature on radioactive contaminants of soil and plants see the paper by Polyakov and Germanova [31].

accumulates to a considerable extent in the roots, scarcely penetrating to the upper organs. So when a radioactive isotope and its daughter products are present in the nutritive medium in a state of radioactive equilibrium, the equilibrium relation is sharply destroyed as they are taken up by the roots and transferred to the above-ground organs, the parent becoming separated from its decay products.

A phenomenon analogous to this has been observed [30] in relation to certain short radioactive chains in the fission product group. For example, even when equilibrium solutions of $\text{Sr}^{90} + \text{Y}^{90}$ react with soils, the parent and daughter isotopes were observed to be absorbed differently. The separation was particularly marked on extracting the $\text{Sr}^{90} + \text{Y}^{90}$ from the absorbed state (after radioactive equilibrium had been reattained) into a neutral salt solution. When these were taken up via the roots from a soil containing $\text{Sr}^{90} + \text{Y}^{90}$ in equilibrium the parent strontium outstripped the yttrium daughter. The activities of plant specimens taken not long after uptake of this isotope pair had begun, were not constant, but increased with time as the daughter yttrium accumulated to restore equilibrium. A similar effect is found on taking up the radiostromium via the roots into the above-ground organs not only in the case where the isotopes are derived from a soil, but also in pots filled with quartz sand containing $\text{Sr}^{90} + \text{Y}^{90}$ in equilibrium.

But when the $\text{Sr}^{90} + \text{Y}^{90}$ are further transferred throughout the organs (e.g., from lower to higher leaves) it is found that the yttrium daughter is relatively more mobile than the parent strontium. The clearest evidence for the greater Y^{90} mobility relative to the Sr^{90} in the above-ground transfer processes is found when the $\text{Sr}^{90} + \text{Y}^{90}$ is introduced via separate leaves, other leaves from other parts of the plant being removed for observation.

When the $\text{Sr}^{90} + \text{Y}^{90}$ is not introduced through the roots but via the leaves of a sunflower, it is found that the activities of specimens (taken from leaves higher up than the treated ones) fall by a factor of 8-10 by 10-15 days after taking, which implies that the shortlived daughter yttrium is predominantly transferred to these leaves, the ratio of strontium to yttrium in these leaves being several times less than the equilibrium value.

These data prove firstly, that when the uptake, transfer and distribution in plants of radioactive materials which are genetically related nuclides are studied, we must allow for phenomena in which radioactive equilibrium is disturbed, since serious errors result from ignoring this fact. Secondly, they show that when computing radiation doses to the tissues of various organs in which the uptake is related in a similar manner, we must allow for the differing uptakes and distributions of parent and daughter nuclide.

This whole exposition leads us to conclude that when studying the actions of radioactive substances on plants we encounter an extremely complex problem in agronomic science, primarily due to the enormous variety of conditions which may occur in any experiment, and to the difficulty of defining an accurate biophysical picture of radiation action on plants.

The complexity of this problem must particularly be borne in mind in relation to the numerous possibilities of raising the yield of crops and the quality of agricultural products by using such techniques as soaking the seeds in solutions of radioactive materials or inserting small amounts of radioactive material in the soil [33, 34]. This problem, in spite of its long history, is still extremely confused, and the deductions are extremely contradictory. We may make the following comments on the basis of the material which has accumulated as to the effect of such methods on plants, and as to the effects of radioactive substances in general.

Numerous experiments are described in the literature in which accelerated growth and development and raised yields are claimed from the action of radioactive substances on plants. These results were obtained in experiments in which the dose range was extraordinarily wide, beginning with experiments in which the seeds were soaked in solutions at concentrations of 0.5 $\mu\text{C}/\text{liter}$ and ending with vanishingly small 'homeopathic' doses of radioactive substances introduced into the nutritive solution or into the soil, these being enormously less than the natural activity of the medium.

Meanwhile over this very wide dose range, numerous experiments have shown either no stimulant action on plants, or else the action was stated to be negative.

Some workers start from the concept that the naturally radioactive elements are just as necessary for plant life as are the other essential non-radioactive elements (e.g., trace elements), when investigating the actions of small doses of radioactive materials on plants. It is asserted that the radioactivity is a factor which influences the role of the naturally radioactive materials in the organism [33].

The work of Vinogradov, which appeared comparatively recently, is of great interest in this connection;

he showed in a unique experiment with the naturally radioactive isotope K^{40} that its activity had no material effect on the growth and metabolic rate of the mold *Aspergillus* [35]. The results from this experiment constitute an extremely critical contribution to the debate on the absolute need of plants for a natural level of radioactivity.

The contradictory nature of the whole of the material on the stimulant action of radioactive substances and on their being necessary to plant life impels us to consider this problem far from solved at the present time and as requiring further and more profound study, particular note be taken of the dosimetric picture and particular care being taken to elucidate the conditions under which the observed effects can be reproduced systematically.

In the future, more profound study of the actions of radioactive substances on plants should be carried out over a wide range of radiation doses and in various controlled experimental conditions with more detailed attention to the dosimetric factors than has hitherto been the case, since the practical and theoretical importance of such research is not restricted to the doubtful prospect of using radioactive substances for stimulating the growth and development of plants directly, and thus improving the yield or the quality. In practice, as may be concluded from the above discussion, the real problem is to obviate any rise in the activity of agricultural products caused by the scattering of fission products over the Earth. The use of radioactive substances as stimulants or "radioactive fertilizers" is bound to lead to a rise in the general background of radioactivity in agriculture which is certainly undesirable. Hence the search for the practical aspects of radiation stimulation must be directed primarily to their actions on seeds, tubers, etc., the radiation being applied externally via X- or γ -rays. Irradiation in this fashion is very much simpler, and the accuracy of the dosimetry is much greater than when the seeds are soaked in radioactive solutions or when "radioactive fertilizer" are placed in the soil, for instance; in addition, external irradiation does not cause a rise in the activity of the product.

Although the results from work on the direct physiological action of external radiation on seeds or vegetating plants* give us so far no firm basis for asserting that we will in this way be able to render any positive effects stable; this research must not only be directed to giving results in the light of the general problems of radiobiology, but also to answering the practical problems of agriculture. In this case interest will not only attach to particular stimulation effects, i.e., more rapid growth and increased yield, but also to the search for ways of regulating metabolic processes in order to change the compositions of plants and to cause the plants to accumulate compounds which are of interest in practice (e.g., vitamins) [34].

There is, however, yet another important factor impelling us to consider the many-sided development and profound investigation of the actions of ionizing radiations in general (and of radioactive substances in particular) as being a very urgent present problem, to be dealt with under the most varied experimental conditions. The urgency of such work is connected with the genetic action of radiation, and with the prospects of using radiation for selection purposes, which have lately become apparent.

While the genetic action of ionizing radiation has been known for a long while, it is only now with the enormous extension of experimental facilities that have become available with the development of atomic energy, that reliable data have become available on the chances of obtaining results of value by the use of radiation on agricultural plants.

We do not propose to give here either a general evaluation of the practical prospects of radiation genetics and selection in agriculture, nor to consider the special genetic and selection problems which arise in this connection. They will be dealt with in detail in another paper at this conference; however, I shall deal with one of these questions which is of more general importance in connection with the prospects in that section of the work which requires a combined attack by various scientific disciplines.

One of the most important recurring problems in this field is the elucidation of opportunities for producing directed changes in the heredity of plants by devising the appropriate irradiation schemes. Contemporary biophysics and radiation genetics dispose of general methods of comparison, detailed study, and establishment of the most varied modes of radiation action (in the wide sense of the word).

In this respect, external irradiation is of great interest, but so are a variety of conditions of irradiation produced by radioactive materials taken up by plants. By using radioactive isotopes of various elements for this

* A summary of these results is given in Kuzin's paper [34].

purpose and making use of their special distributions in organs and their localization in tissues while bearing in mind their types and energies of decay, we may produce various types of irradiation and approach a solution of the problem in this way.

It is also of interest to see whether one can change the radiosensitivities of plants by adjusting the conditions of nutrition and other factors, while seeking conditions most favorable for radiogenetic and radioselective purposes. For this purpose we undoubtedly require the united effort of radiobiologists, biophysicists and selection geneticists directed to the elucidation of the nature of radiation action on plants and to seeking means of consciously directing radiobiological effects, including their genetic consequences.

From this point of view, the effect on plants of factors such as neutron irradiation is of interest. One of the characteristic features of neutron action (we have in mind primarily slow neutrons) is its relation to the chemical and nuclide composition of the tissue. For example, the distribution of the energy absorbed by the plant tissue on neutron irradiation between the various ionizing particles (protons, α particles, recoil nuclei, electrons, γ -rays) is to a considerable degree determined by the contents of elements such as nitrogen, boron, etc. Changes in the content and isotope composition of these elements can change the balance of energy between the various ionizing particles to a very great extent. Nonuniformity occurs in the localization of the primary nuclear reactions and the ionizing particle tracks produced, and hence in the specific distribution of primary acts of radiation action within the cell when neutrons are used.

In this connection it has been found to be possible, by changing the chemical composition of the plant (with regard to nitrogen, boron and other elements), via the nutritional conditions, to produce a known non-uniformity in the distribution of primary acts in the cells of tissues and hence to proceed to the regulation of neutron irradiation effects by producing some specific distribution of primary acts of ionization and excitation.

Calculations [36] show that the fraction of the energy dissipated in a plant tissue which is due to the activity induced by neutron irradiation is negligibly small. But in general, we must surely assign some role in the radiobiological effect to the neutron induced activity. The specific nuclide distributions here, may also be important as their neutron capture cross sections are different. Hence, while the quantitative contribution from the induced activity to the total dose may be small, its importance in producing the specific radiation picture observed on neutron irradiation cannot be excluded, and it may have a special relation to the genetic effects of irradiation.

The experimental study of all these problems and the more complete mastery of radiation effects in neutron irradiation also demand the united efforts of biophysicists, radiobiologists and geneticists.

A deeper and more complete explanation of the mechanisms of the primary processes which produce the physiological and genetic effects of irradiation is of great interest to agricultural science. The development of research in this field should not only facilitate the solution of what are especially radiobiological problems in one of the most promising fields for using atomic techniques to provide the requirements of agriculture - by obtaining new and useful inherited qualities in agricultural plants - but should also contribute to raising the general theoretical level of agronomic science and of biology in general.

We may advance successfully if we take from new atomic techniques in agronomy all that they can provide in the way of a deeper understanding of the phenomena and processes which form the subject of this science, as well as in the way of high accuracy and objective observations and experiments, and thus continually follow the rapid progress of general scientific knowledge.

This present review has been concerned with but few of the theoretical and practical problems of agriculture, in whose solutions all the currently available scientific techniques must be pressed into service, with radioactive isotopes and radiations playing an important part in this. The problems we have not touched upon here concern the use of isotopes and radiations in the protection of plants from pests and diseases, and the conservation and elimination of losses in crops and agricultural products. Isotopes and radiations will find application not merely in agronomic research but also in zoological and veterinary investigations.

The wide field for the introduction of isotope methods (and atomic techniques in general) into agricultural

science includes the use of radiation sources and instruments for investigating the operation of agricultural machines and tools. A number of units for this purpose have been produced for use in agricultural experiments. (For determining the moistness and density of soils, weighing plants while growing, observing the distribution and seepage of irrigation water in soil, etc.). The wide area of application of isotopes and radiations in agricultural science and the varied methodological and technical problems that arise, have given rise to a demand for new methods of measuring radioactivity, and for the refinement of the existing ones. Some of the developments appear to be useful in other fields of science and technology as well.

In particular we may refer to some types of highly sensitive and very stable particle counters that have been developed by Tselishchev at the Timiryazev Agricultural Academy. The demand for an increase in the sensitivity of radiation equipment did not arise accidentally in the agronomic establishment. It arose from the very essence of the specific problems encountered in agronomic science at its present stage of development; these problems have been dealt with briefly above.

E.g., when striving to reduce the size of tracer doses in order to reduce the level of radiation "interference" produced by the tracer itself, it is extremely important to be able to measure small activities as accurately as possible and to have available very sensitive equipment. When the laws governing the uptake and distribution of fission products in plants are studied, it is important to measure minimal activities with the greatest possible accuracy. Since some fission products and a number of radioisotopes used as tracers in agronomic and physiological experiments have comparatively low-energy emissions, we also require apparatus of high sensitivity and high counting efficiency. Experiment shows that development of these, in agronomic laboratories in which isotopes and radiations are used, is of creative interest in methodological questions connected with the use of atomic techniques proper, and this not only raises the level of agronomic work but also aids in solving more general problems of introducing new methods of experimental study in scientific work.

The above discussion leads us to conclude that agriculture and agronomic science, which are connected in many ways with the development of industry and general scientific knowledge, now present a wide field for the application of the new technical means and fresh scientific experimental methods provided by the progress of contemporary physics. We also see that participation in the atomic age sets before agronomy not only the task of using atomic techniques for its own purposes, but also brings forward some entirely new theoretical and practical agricultural problems demanding resolute attention and actively creative study.

We must further the work that has already begun on these problems (in the fields of plant biochemistry and physiology, agrochemistry, soil-working and plant protection), and also develop as rapidly as possible those lines which have for a number of reasons so far not received attention appropriate to their theoretical and practical importance in the general utilization of isotopes and radiations in research.

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